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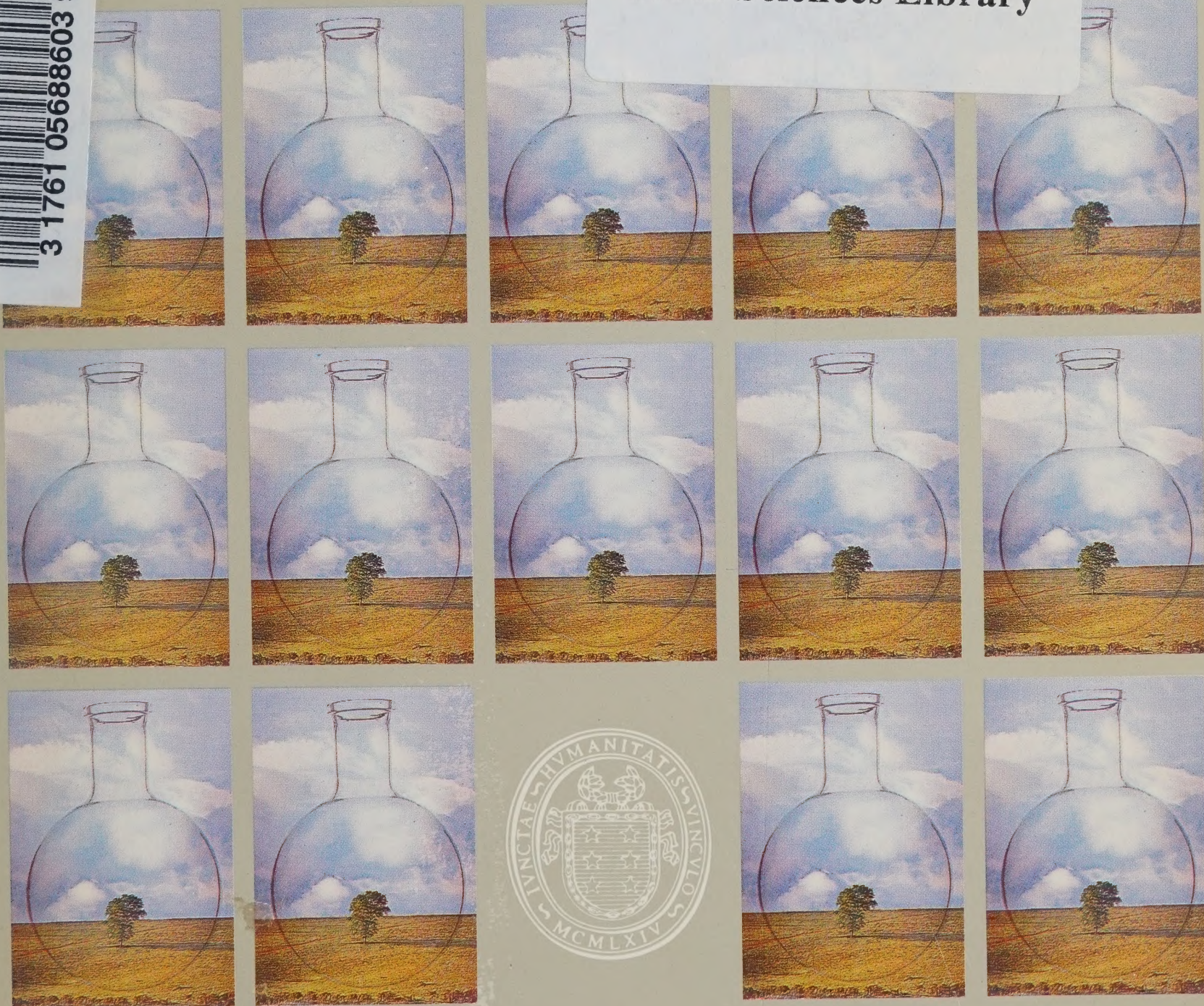
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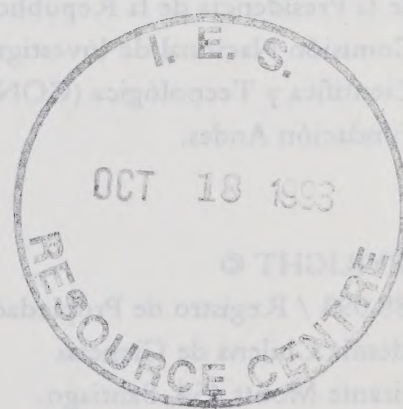
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ANALYSIS AND PROJECTIONS OF CHILEAN SCIENCE

Summary

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EDITORS

Jorge Allende y Tito Urrut
1993

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F. Jaime González Barrios

Alfonso Barrios

En 1993, Santiago

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9	
Chapter I:	ASTRONOMICAL SCIENCES
17	
Chapter II:	BIOLOGICAL SCIENCES
21	
Chapter III:	ENVIRONMENTAL SCIENCES
23	
Chapter IV:	EARTH SCIENCES
27	
Chapter V:	MARINE SCIENCES
31	
Chapter VI:	PHYSICAL SCIENCES
35	
Chapter VII:	MATHEMATICAL SCIENCES
39	
Chapter VIII:	CHEMICAL SCIENCES
43	
Chapter IX:	UNDERGRADUATE STUDIES IN SCIENCE
47	
Chapter X:	PH. D. PROGRAMS IN SCIENCE
51	
Chapter XI:	SCIENTIFIC PRODUCTIVITY
59	
Chapter XII:	INTERNATIONAL SCIENTIFIC COOPERATION
63	
Chapter XIII:	FUNDING OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH IN CHILE
65	
CONCLUSIONS AND RECOMMENDATIONS	

Prologue

As host of the 1993 General Assembly of ICSU, the Chilean Academy of Sciences felt the responsibility of informing our distinguished visitors about the present state of science in Chile and about our future perspectives.

In order to achieve this goal, we started during 1992 to conduct an in depth study of the situation of scientific research and training in eight large areas of science: astronomy, biology, chemistry, earth sciences, environmental sciences, marine sciences, mathematics, and physics. These studies were carried out by groups of specialists in these areas recruited from Academy membership and from the disciplinary societies members of the ICSU National Committee. Each of these groups prepared a chapter dealing with their area of science and also prepared a directory of the active researchers in their field.

In addition, the study included "horizontal chapters" dealing across disciplines with: scientific productivity; undergraduate science training; post-graduate science training; international cooperation in science, and financing of science in

Chile. A final chapter puts together the main conclusions and recommendations emerging from the study.

Since this study will be specially useful and helpful for Chilean institutions, authorities and individuals and also for interested individuals in Latin America, the full-length chapters generated by these groups of scientists will be published in Spanish. A separate publication will contain the Directories. The main list will contain the name, addresses and fields of research of approximately 1,400 active scientists working in Chile. A second list contains the addresses of 350 Chilean scientists working in other countries.

The aim of the Academy in compiling this second list is to facilitate contacts with these expatriate Chilean scientists and to attain their participation in our efforts to develop science in Chile. Finally, the Directory also contains information about the major scientific societies in Chile.

For non-Spanish speaking participants in the ICSU Assembly and for all those others interested to know about Chilean science, we have prepared this English Summary version of the Academy study. Our hope is that it will provide its readers with the main conclusions arrived at in each one of the specialized chapters. In addition, the summary contains a full-length translation of the final chapter that contains the general conclusions and recommendations of our study. We hope that through this volume scientists from other latitudes will learn of our concerns and our hopes and will also help us by sending us their ideas, criticism and support. The Chilean scientific community wants and needs closer ties with the international scientific community and is certain that the visit of so many of its distinguished leaders on the occasion of 1993 ICSU General Assembly will be very helpful.

Chapter I

ASTRONOMICAL SCIENCES

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I. ASTRONOMICAL CENTERS

Among scientific disciplines astronomy has a privileged position in Chile since our sky is one of the most favorable in the world for astronomical research. It is a natural resource from which we wish to obtain the best possible advantage. The development of astronomical research performed by Chilean astronomers in Chile has thus become a high priority and a real challenge which we must meet.

In Chile there are five Chilean centers and three international observatories where teaching and/or research in astronomy take place.

CHILEAN CENTERS

1. Two long established centers are the Departamento de Astronomía of the Facultad de Ciencias Físicas y Matemáticas of the Universidad de Chile, with 18 Chilean astronomers; and

2. The group of Astrophysics of the Facultad de Física of the Pontificia Universidad Católica de Chile, with 3 permanent astronomers and 2 visiting professors, one under the German DAAD program of the Service of Academic Exchange, and one "on leave" from the University of Meudon.

Two centers where astronomical activities are incipient are:

1. The group of Astrophysics of the Facultad de Ciencias of the Universidad de La Serena, where a group of 5 members of the Departamento de Física started working in astronomy a few years ago; and

2. The Facultad de Física of the Universidad de Santiago de Chile, where one astronomer at the Departamento de Física is doing some research in astronomy.

In addition to these centers, there is an institute where only research is done, the Instituto Isaac Newton, with a group of four members.

These institutions have the following facilities:

The Departamento de Astronomía of the Universidad de Chile has three branches:

1. The Observatorio Astronómico at Cerro Calán, in Santiago, (where the main offices are located), with two telescopes: a Repsold Meridian Circle and a Danjon Impersonal Astrolabe. Its main facilities include a library, digitalized measuring machines, a time service based on a cesium atomic clock, computing facilities at the Center for Digital Image Processing, sky charts, photographic laboratory and electronic mail (bitnet and internet).

2. The Radio Observatorio at Maipú, with a 45 MHz telescope and an electronics laboratory.

3. The Estación Astronómica at Cerro El Roble, with a Maksutov Astrograph and a photographic laboratory.

In addition to this equipment, a millimetric radiotelescope which is property of the University of Columbia, is located at Cerro Tololo, for the use of astronomers of the Universidad de Chile.

The group of Astrophysics of the Pontificia Universidad Católica de Chile has two locations:

1. The Observatorio Manuel Foster, at Cerro San Cristóbal, with one 1 m reflector telescope.

2. The main offices at the Campus San Joaquín, in Santiago, with extensive computational facilities, library, photographic laboratory, measuring machines connected to the computing system, sky charts and electronic mail (bitnet and internet).

The other Chilean institutions have no comparable facilities.

INTERNATIONAL OBSERVATORIES

The three international observatories, all located about 450 kilometers north of Santiago in the city of La Serena, are:

- a) Cerro Tololo Inter-American Observatory (CTIO), operated by the USA organization AURA Inc. (Association of Universities for Research in Astronomy);

- b) European Southern Observatory (ESO), at Cerro La Silla, operated by an

association of European countries, which includes Belgium, Denmark, France, Germany, Holland, Italy, Sweden, and Switzerland; and

- c) Carnegie Southern Observatory (CARSO), at Cerro Las Campanas, operated by the private corporation Carnegie Institution of Washington of the United States. The University of Toronto, Canada, also operates a telescope there.

It is important to describe briefly here how these observatories became a reality. In 1958 Prof. Federico Rutlant, Director of the Observatorio Astronómico of the Universidad de Chile, (later on Departamento de Astronomía) was invited by the USA Government to visit the most important astronomical observatories of that country. During his visit Rutlant discussed with Drs. G.P. Kuiper and W. A. Hiltner, from Chicago University, the possibility of a joint program between the Universities of Chicago and Chile, in order to establish an astronomical observatory in some place of the Chilean mountains, considering the very favourable climatic conditions for astronomical observing which were expected to exist in many of the intermediate height summits. It was this idea, extended afterwards to all the Universities members of AURA Inc., which gave birth to Cerro Tololo Inter-American Observatory. The site survey to find the best possible place for the new observatory was directed by Dr. J. Stock, together with a group of astronomers and assistants of the Universidad de Chile (Moreno, 1990). The Universidad de Chile gave all the support necessary for this survey.

The search concluded after three years of work, with the selection of Cerro Tololo as the site for the new observatory in November 1962.

Because of the success of this initial site survey, two astronomers of ESO, an institution which was looking for a site in South Africa, came to visit Cerro Tololo and another site in December 1962. This visit directed the interest of ESO from South Africa to Chile. The decision to install the observatory in Chile was taken during the

meeting of the ESO Council, in May 26, 1964.

At about the same time a cooperative agreement between the Carnegie Institution of Washington and the Universidad de Chile was signed (August 6, 1963). This agreement lead to the installation of the Carnegie Southern Observatory at Cerro Las Campanas. A revised cooperative agreement was signed in July 31, 1969.

During 1970 a new agreement was signed, this time with the University of Toronto, Canada, for the installation of a telescope at Cerro Las Campanas, after an arrangement between CARSO and the University of Toronto.

Considering the optical surfaces of the telescopes installed in these observatories and the instruments which operate with these telescopes, we have now in Chile the biggest concentration of optical facilities in the world to do astronomical research.

The international observatories work under very special legal conditions granted by the Chilean Government. The guaranties and prerogatives granted to all of these institutions are the same. However, the access to the telescopes that these institutions give to Chilean astronomers has not been equal.

Chilean astronomers may get observing time in the telescopes of northern Chile by either of two means:

1. By a right to their use established by contract, which means a percentage of the observing time as a granted time based on the quality of the research projects;

2. With permission of the authorities of the observatory.

The first case corresponds to the observatories whose mother institutions signed agreements with the Universidad de Chile. Cerro Tololo grants 10% of the observing time to the astronomers of the Universidad de Chile, and Cerro Las Campanas, with the telescope of the University of Toronto, grants 10% of the observing time to all Chilean astronomers.

The second case occurs only at Cerro La Silla since the Chilean Government signed an agreement with ESO in which no granted time for the Chilean astronomers was established. Fortunately, this agreement has been changed.

In all these cases, observing time is granted in a competitive peer review system, after presentation of projects which are graded according to the rules established by the observatories.

II. FORMATION OF HUMAN RESOURCES

In this moment there is no formal undergraduate teaching of astronomy at the Chilean universities. Starting in 1966, the Departamento de Astronomía of the Universidad de Chile, granted the degree of Licenciado (Licentiate, a six year program including a thesis). Eight students were graduated up through 1975, and five of these students obtained afterwards their Doctors degree (in USA, Canada, France and Italy); five of the Licenciados (four of them with a Ph.D. degree) are now working at the Departamento de Astronomía of the Universidad de Chile.

The licentiate degree of Science was replaced in 1975 by postgraduate studies leading to a Master of Science degree.

Admission to the Master's program requires the degree of Licentiate in Sciences (Physics) or equivalent. The studies require 5 semesters, including 7 compulsory courses and 3 elective ones (one of which must be in Physics) plus a thesis corresponding to an original research problem. The students do practical work at the international observatories. The stay in the program is about two years and a half.

During the first year of the decade of the '80s, the admission to the Master's program was almost null, for reasons related to the difficulties which the universities had to hire new personel. For this reason, only two students got their Master's degree at the beginning of the '80s, and one in 1985. In all, since the beginning of the program, six

students have graduated. Three of them have received a Ph.D. degree in foreign countries (USA, Canada, France) and three are at this moment studying in USA to get their Ph.D. Of the three students with the Ph.D. degree, one has left astronomy and is in private activity. Two more students are preparing their thesis, and four are still taking courses.

In all, the thesis of Master in astronomy have produced eleven publications, an average of 1,8 publications per thesis.

In the Pontificia Universidad Católica de Chile there is no postgraduate program in

astronomy. However, there is a Ph.D. program in Exact Sciences with mention in Physics, in which the students can take courses and do their theses in astronomy. Those interested in the subject also receive training in the observatories of the north of Chile. During 1992 there were 2 postgraduate students in physics with interests in astrophysics; one of them finished his Master's degree and is now studying in Germany to obtain his Ph.D. degree. The other one still has to take his qualifying examinations.

III. HUMAN RESOURCES

By the end of 1992 there were 33 persons working in research in astronomy at Chilean institutions: 18 at the Universidad de Chile, 5 at the Pontificia Universidad Católica de Chile, 4 at the Instituto Isaac Newton, 5 at the Universidad de La Serena, and 1 at the Universidad de Santiago de Chile.

The average age of the persons is 49.4 years. There are no astronomers younger than 34 years, and the averages per institution are all high and very similar. The highest average corresponds to the Universidad de Chile.

Analyzing the degrees of the people working in astronomical research it is found that 16 of them have a Ph.D. degree, and 3 of

them a Master's degree. The Ph.D. degrees correspond mostly to "younger" people (12 out of 16 correspond to astronomers between 34 and 50 years). This shows that the different institutions now prefer to hire only persons who have a Ph.D. degree. In this moment (1992) the number of persons who have the Ph.D. degree are: 8 at the Universidad de Chile, 5 at the Pontificia Universidad Católica de Chile, 1 at the Universidad de La Serena, 1 at the Universidad de Santiago de Chile and 1 at the Instituto Isaac Newton. In all, the number of persons with the Ph.D. degree has changed from 1 in 1960 to 16 in 1992.

IV. AREAS IN WHICH RESEARCH IS BEING PERFORMED

The main research subjects in the different academic units are:

1. Universidad de Chile. Reference systems, stellar photometry and photography, stellar evolution, galactic structure, gaseous nebulae, studies of the Magellanic clouds, extragalactic astronomy, and observational cosmology.

2. Pontificia Universidad Católica de Chile. Stellar astrophysics and extragalactic astronomy.

3. Instituto Isaac Newton. Stellar clusters, mainly globular, stellar populations in the Magellanic Clouds, search for novae and supernovae, and archaeoastronomy of Easter Island.

4. Universidad de La Serena. Variable stars, modelling of light curves, and solar-type activity in late-type stars.

5. Universidad de Santiago de Chile. Planetary nebulae, and ring galaxies.

V. SCIENTIFIC PRODUCTIVITY

A) Number of publications. Fig. 1 presents statistics of the astronomical publications from 1980 up to 1992 (taken every three years) by the 5 Chilean institutions mentioned in section I. The publications have been divided in three groups: publications in Journals which are included in the Citation Index of the Institute for Scientific Information (ISI publications), publications in Journals which are not indexed in the Current Contents (No ISI), and presentations in Congresses published in extenso (P/C). ISI publications predominate, and the number of publications increases with time.

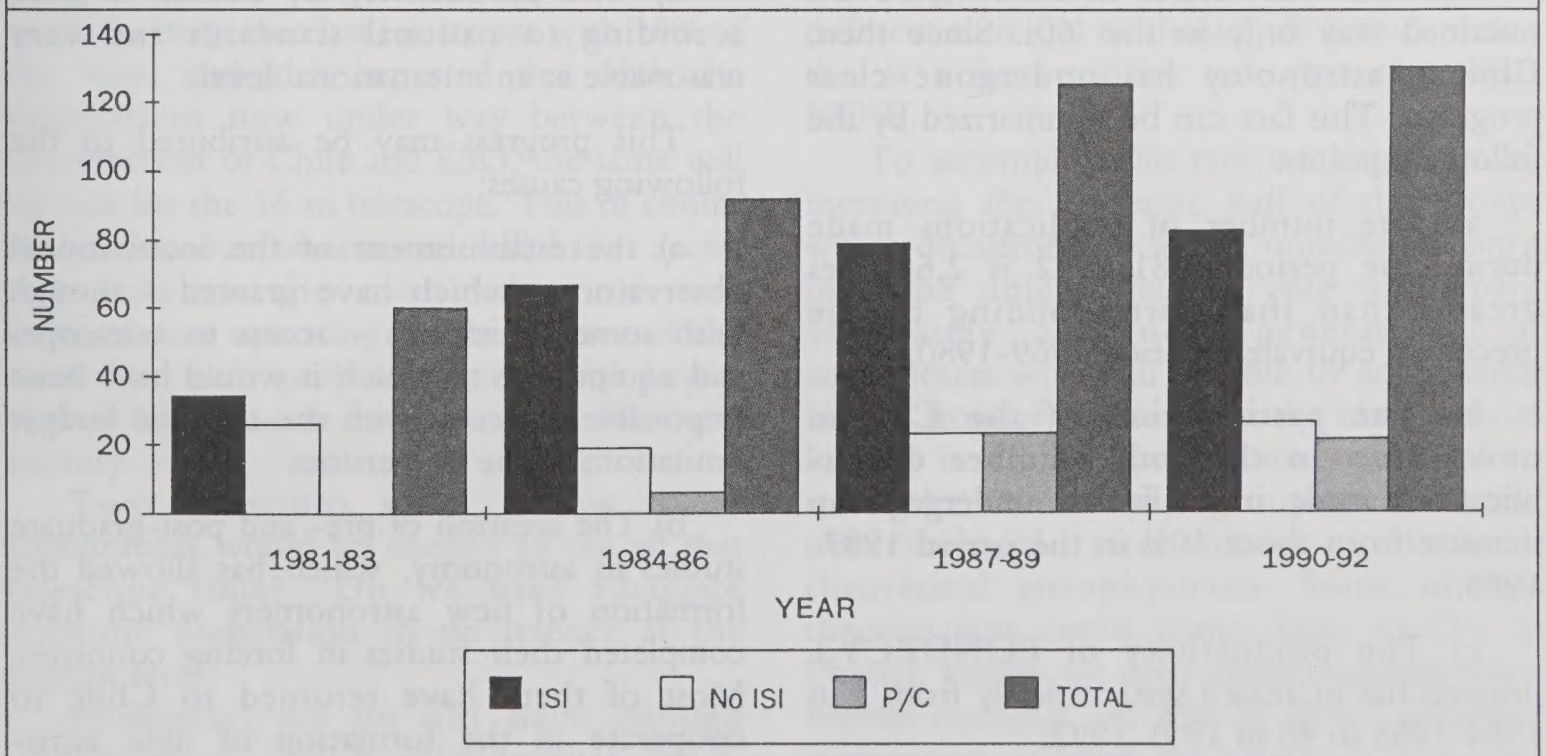
In what follows we will analyze only the publications ISI, which are the most important.

Krauskopf and Pessot (1980, 1983, 1985, 1987, 1989) have analyzed the scientific productivity at the universities. Their data in the astronomical sciences include both the publications of the University scientists and those made in the observatories of the north of Chile by astronomers living in Chile. According to their results, the productivity of the Chilean universities with respect to the total astronomical productivity in the country (international observatories plus Chilean universities) has increased from about 10% in 1976 to about 25% in 1988.

B) Research in astronomy at the university level is financed on the basis of 4 main sources:

FIGURE 1

Astronomical publications



a) Internal funds of the academic units.

b) Funds from the Central Research Offices of the Universities.

c) Fondo Nacional de Ciencia y Tecnología (FONDECYT) projects. Up to this date, only Universidad de Chile and the Pontificia Universidad Católica de Chile have received grants from these funds.

d) External funds, national and international.

FONDECYT funds obtained by presentation of projects are important for astronomy. The total number of projects approved since 1982 is 65. The percentage of projects approved with respect to the number of projects presented is very high, reaching an average of 70% in the 11 years of existence of FONDECYT (FONDECYT, 1992).

An analysis of the productivity of the FONDECYT projects has been made, showing that has increased from 3 publications during 1984-1985 to 46 during 1991-1992.

C) External Projects. Both the Universidad de Chile and the Pontificia Universidad Católica have obtained grants from United Nations Development Program (PNUD), which have been used mainly to get computational equipment adequate to the present needs. There has also been cooperation from the universities, from Fundación Andes, the international observatories of the country, and other national and foreign institutions.

Among the foreign institutions we can mention: Max Planck Institute, DAAD, Alexander von Humboldt Foundation, GTZ and Volkswagen Stiftung (Germany); NASA, Harvard Smithsonian Center for Astrophysics and McArthur Foundation (USA); Laboratory of Astrophysics and Space Techniques at Meudon, project DENIS (dependent on an international group with seat in France), and projects under the Cooperation of the French Government (France); the University of Leiden (Holland); the Universities of Rome, Bologna and Padova (Italy); and the Sternberg Institute and the Science Academy of Moscow (Russia).

VI. CONCLUSIONS

Astronomical research in Chile started in a sustained way only in the '60s. Since then, Chilean astronomy has undergone clear progress. This fact can be summarized by the following points:

a) The number of publications made during the period 1981-1992 is 2,6 times greater than that corresponding to the preceding equivalent period 1969-1980.

b) The participation of the Chilean universities in the total number of publications made in Chile has undergone an increase from about 10% in the period 1987-1988.

c) The productivity of FONDECYT projects has increased systematically from 3 in 1984-1985 to 46 in 1991-1992.

d) The productivity by author is good according to national standards and very reasonable at an international level.

This progress may be attributed to the following causes:

a) the establishment of the international observatories, which have granted - though with some limitations - access to telescopes and equipments to which it would have been impossible to access with the extreme budget limitations of the universities.

b) The creation of pre- and post-graduate studies in astronomy, which has allowed the formation of new astronomers which have completed their studies in foreign countries. Most of them have returned to Chile to cooperate in the formation of new astro-

nomers and to help in the development of new research fields.

c) The creation of FONDECYT, which has made funds available for research at levels that the universities alone would not have been able to grant.

There are, nevertheless, some deficiencies which we must try to correct. These may be summarized as follows:

a) All of the astronomical centers must agree that to have real progress in astronomy,

it is necessary but not always sufficient that every person working in this discipline obtain a postgraduate degree and that only persons of the highest possible level should be hired.

b) Considering the average age of astronomers community we must try to form more young astronomers and obtain positions for them in the different institutions.

c) It is evident that some important specialities are missing. Theoreticians and instrumentalists are particularly needed.

VII. GOALS FOR THE FUTURE

The goals for the future are, in part, given from the preceding considerations.

Towards the end of the present century the greatest telescope of the world, made of four mirrors with a diameter of 8.1 m, which will synthesize a great telescope of 16 m (property of ESO), will be operative in northern Chile, near Antofagasta. The twin southern telescope of project Gemini, also with a diameter of 8 m (property of a society between USA, UK and Canada) will also be in operation in Cerro Pachón (near Cerro Tololo), as well as a telescope of 6.5 m of the Carnegie Institution of Washington, at Cerro Las Campanas. Chilean scientists will have access to these two last telescopes with 10% of the time, and it is expected that with the negotiations now under way between the Government of Chile and ESO, the same will be true for the 16 m telescope. This of course means that our astronomers will have access not only to the most advanced instrumentation operating on the surface of the earth but most probably also to the largest optical telescope to be built until the next century.

Two questions arise. How many astronomers would be needed to use all that telescope time? Do we have adequate scientific preparation to do science at the highest level?

Evidently, we do not have enough astronomers, and hardly at that level.

Consequently, the formation of astronomers is of utmost importance. How many astronomers we should have in Chile in order to fulfill these expectations? Using international statistics, we conclude that we should have at least 5 astronomers per million inhabitants, which implies a total of about 70 astronomers. We should increase the present numbers of astronomers by a factor of about 2.5. This increase should be gradual and constant. If we assume a period of 15 years to reach this goal, we should be forming an average of 2.6 astronomers per year. This implies that we should be accepting about 5 students per year, allowing that some of them will go to different activities or abroad. It is evident that this is a first priority task that must start NOW.

To accomplish this task we must start by increasing the academic staff of the groups which do astronomy in our universities, since only the universities are able to prepare adequately the new generations of astronomers who will be able to do research in the frontier of science in the observatories located in Chile. In addition, we need to strengthen university groups with some observational astronomers and with theoretical astrophysicists. Some of this theoreticians could come from Ph.D's in Physics. Finally we need instrumentalists who, besides teaching, are able to design adequate instruments to work the telescope in accord

with the needs of the scientists who make the observations.

At the present time, the Chilean scientific community is engaged in strengthening the Ph.D. programs in different disciplines. With the reinforcements mentioned in the preceeding paragraph, and with the collaboration of the international observatories, this would be possible for astronomy. This Ph.D.

program could be directed not only to Chilean students, but could be extended to all Latin-America.

Nevertheless, we must assure that our graduates have the opportunity to get post-doctoral training abroad in order to broaden their contacts with the international community.

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Chapter II

BIOLOGICAL SCIENCES

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Approximately 680 scientists are actively engaged in research in the area of the life sciences in Chile. This low number is disconcerting, particularly when compared to the high representation of the scientific population in developed countries. Of equal concern is the fact that this group, which represents about 50% of all Chilean scientists, has an average age of over 45 years. This "aging" community reflects the general failure to incorporate sufficient numbers of young people into the research areas.

The present report summarizes some of the characteristics and needs of this small community of scientists working in the area of biological sciences.

1. IMPACT

A recent study made by the Institute for Scientific Information (Welljams-Dorof 1993) showed that in the period of 1981-1991, Chile contributed 20% of the worldwide publications in biological sciences that originated from South America. If the population of the country is taken into consideration, both Chile and Argentina are very efficient in regard to publications. Sixty percent of Chilean publications in biological sciences correspond to experimental biology and medicine (excluding clinical research) and 10% are from the fields of biochemistry and biophysics. Other disciplines contribute

between 1 and 5%, specifically: pharmacology (4%), neurosciences (4%), environmental sciences (4%), cellular biology and microbiology (4%), zoology (4%), reproduction and development (2%), molecular biology and genetics (1%), and immunology (1%). The publications originating from Chile since 1986, from all the areas mentioned above, are those which have had the highest impact (as measured by citations), as compared to the publications originating from other Latin-american countries.

2. FINANCIAL SUPPORT

In the last six years, 58% of the biologists working in Chile have received financial support for their research from national sources, specifically from the FONDECYT (Fondo Nacional de Ciencia y Tecnología);

31% have been funded by international research projects.

3. SCIENTIFIC SOCIETIES

The community of biologists is well organized in scientific societies, of which the Chilean Society of Biology (Sociedad de Biología de Chile) is the most important. There are nine affiliated societies devoted to the specific disciplines. The Society of Biology publishes two scientific journals, *Biological Research* and *Historia Natural* (Chilean Natural History).

4. GEOGRAPHICAL AND INSTITUTIONAL DISTRIBUTION

The research done in Biology in Chile can be classified as "first world" and "third world" quality, first world indicating that the results published by these researchers have an impact and acceptance on an international level, whereas the third world type of research is generally published in journals of low impact and generous editorial policy. This is most likely a result of the uneven distribution of human resources throughout the country. Of the 680 biologists working in Chile, 65% work in Santiago, 20% are located in the cities of Concepción and Valdivia, and the remaining 15% are distributed throughout the country. About 85% of the biologists are affiliated to the four largest and traditional universities, out of the total of 22 universities that are affiliated to the council of university presidents.

5. PROFESSIONAL TRAINING

Only 33% of the biologists in Chile have received a Ph.D. degree. Another 51% have a professional degree (medicine, veterinary, etc.). Entrance to the doctoral programs in biology during the past 5 years has averaged 27 students per year. In the same period, 51 students received their degree (10 per year). However, not all of these graduates remained in Chile and only an average of 1.7 new Ph.D. were incorporated per year into the community of biologists.

In the last five years, CONICYT (Comisión Nacional de Ciencia y Tecnología) has awarded 87 fellowships to graduate

students in Ph.D's programs in biology, a number which represents only 40% of those young people that apply for these fellowships. It is evident that the number of students opting for a scientific career in biology is alarmingly low and that the number of fellowships even lower. It is obvious to Chilean scientists that there is a serious deficiency in the system that fails to attract and train young scientists and that the community of increasingly aged scientists persists. One additional determining factor in this area is the limited university budgets that do not allow for the incorporation of new young scientists which have been trained in the local doctorate programs.

The absence of a strong policy to increase the scientific community compounds the lack of motivation of young Chilean to become scientists, as well as favoring the immigration of young biologists to developing countries.

6. CONCLUSIONS

It appears highly probable that Chile will face future difficulties in its development if steps are not taken now to increase its scientific human resources. Among these, a priority would be the training and subsequent retention of its young scientists. The country has the human and laboratory resources to increase significantly the number of young scientists in biological sciences.

A political commitment is required to ensure that the programs for the formation of new scientists increase their efficiency in the next few years by at least five fold. What seems to be a more complicated task and of longer duration will be the finding of the means to retain young scientists in Chile. As long as new alternatives for employment are not developed (industry, research institutes, and community colleges, etc.) the principal option that could be used to keep scientists in the country is the Chilean universities themselves. It is very important that the Chilean university system modifies the academic career in such a way that, by means of competitive mechanisms, the best human resources found in the country can be incorporated into university faculties.

An extensive study carried out during the last three years has showed that approximately 200 Chilean biologists are working outside the country. Around 90% of these are found in the USA and Europe. One third are less than 40 years old and another third is between 40 and 49. Ninetyfive percent of these scientists are interested in establishing an academic link with their Chilean colleagues living in Chile and 47% are ready to return to live in Chile. Up to 76% of the scientists younger than 40 years of age would consider returning to Chile. A notable difference

between these biologists and their Chilean counterparts is that 60% of the Chilean biologists working outside the country possess a Doctorate degree.

The return to Chile of a significant number of biologists, the majority of which are both young and highly qualified depends exclusively on a political commitment that the Chilean Government needs to make. This would be an efficient means to increase the small community of biologists who work in Chile and also to improve the average age of this community.

Chapter III ENVIRONMENTAL SCIENCES

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Environmental Sciences have been included in this volume mainly because they should provide knowledge and information to help in the decision-making process and thereby improve the relation between human population and its environment. The challenge for these sciences is to develop a coherent body of knowledge and models linking these two elements.

Consequently, this field has been defined as the search for new knowledge, a theoretical framework and practical solutions leading to a biophysically sustainable development.

Numerous difficulties have been faced in trying to present a description of the present status of the Environmental Sciences in Chile. There is no national organization or society, or any journals where scientific findings are reported. People working in the area pertain to universities, institutes and private organizations and publish their findings in a broad spectrum media.

To convey an idea of the present condition of these sciences, six topics were selected for case-studies and specialists in each area were asked to write sections of this chapter. These areas are: energy, water and air pollution, biodiversity, human settling and global change.

In order to offer a recent quantitative characterization of the sciences in terms of publications, research projects, and active

scientists, several sources were explored including files from CONICYT, CIPMA, POLTOX, ASFA and Current Contents-Life Sciences. The results of the survey for the period 1988-1992 can be summarized as follows. The trend in the number of communications is difficult to ascertain because figures for the first and last years are probably incomplete. From a total of 763 publications only a 20% appeared in international journals. Over the five-year period 83 research projects were funded by CONICYT, but it was not possible to report on the number of internationally funded projects because of lack of information. In Chile there are about 210 scientists working exclusively or occasionally in Environmental Sciences.

The case study covering the six subjects mentioned above was based on answers to questionnaires sent to selected scientists and on the personal acquaintance of each author within his area. Because of differences in

quantity and quality of the responses received and other factors, the six sections differ considerably. However they all provide information on active research groups, teaching, funding and priorities for development.

The most important findings are as follows. Environmental research in Chile is presently closer to applied rather than to basic research, involved in problem-solving rather than the understanding of natural processes. This is partially responsible for the kind of reports most frequently used: oral presentations in workshops and conferences.

Frequently there were problems in deciding what areas are indeed within the Environmental Sciences scope or who are the legitimate researchers in this field. There were many cases of scientists dedicating a fraction of their time to this area who do not consider themselves environment researchers. Therefore, there is some overlapping between this and other chapters.

A most important conclusion of this study is that there is a need to stimulate the basic aspects of these sciences, dealing with the fundamental questions on how society relates with its environment. An important feature of

Environmental Sciences is its transdisciplinarity, combining physical, chemical and biological aspects with social sciences. Some scientists working in better developed disciplines tend to consider this area as "soft" science. However, this attitude should be replaced by serious respect since this area is full of opportunities for the application of theory and means to approach a field with immediate relevance to society. Furthermore, because of its proximity to urgent environmental problems, this area should be the source of contact with policy-making spheres and could be a bridge to improve the rapport between them and the scientific community.

In conclusion, this analysis of the present status of Environmental Science in Chile illustrates the urgent need to reorganize and strengthen their presently sparse activities. Steps to be taken are the formation of a national society where Chilean environmentalists could meet and develop crucial interdisciplinary relations. It is necessary to define together with governmental officials a development project where underdeveloped key areas are stimulated. Periodic scientific meetings should be held and a journal is required.

Chapter IV EARTH SCIENCES

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Research in Earth Sciences is mainly concentrated at the Universidad de Chile, Universidad Católica del Norte, Universidad de Concepción and the Servicio Nacional de Geología y Minería (SERNAGEOMIN). The latter is the successor of the Instituto de Investigaciones Geológicas (IIG) created in 1957, where various disciplines of basic geology, applied geology and geochemistry first started to develop. Besides, there are government organizations such as the Empresa Nacional de Petróleo (ENAP), and the Corporación del Cobre de Chile (CODELCO) and even private mining companies, that have contributed to the development of Earth Sciences.

Research groups, with few professionals involved, were established in the second half of the 1960's, covering the main areas of Earth Sciences. Today these groups interact developing national and international research projects in the following areas of Earth Sciences: 1) Basic Geology, including the sub-areas of Stratigraphy-Paleontology, Regional-Structural Geology and Tectonics, Quaternary Geology and Volcanism and Petrology-Geochronology; 2) Economic Geology and Metallogenesis; 3) Geophysics; 4) Atmospheric Sciences; 5) Marine Geology and Geophysics; 6) Geochemistry; 7) Engineering Geology; and 8) Hidrogeology. These are the areas and sub-areas analyzed in the present study in terms of their status and productivity during the last 6 years.

The total number of researchers in Earth Sciences is 115, 41 of which have obtained a doctoral degree from a foreign university and 16 have a master degree completed in a foreign or national university. The largest number is concentrated in Regional-Structural Geology and Tectonics (20) and Economic Geology and Metallogenesis (25) which make up 17.4% and 21.8%, respectively, of the total. This correlates well with the earlier start of the research groups and with the fact that these areas are developed at more institutions. Geophysics, developed at only two institutions, includes 14 researchers (12% of the total); Atmosphere Sciences, of more recent development, includes two groups, one of 5 at the Universidad de Chile and the other of 3 at the

Universidad de Concepción, accounting for 6.9% of the total. The number of researchers in other areas is: 6 in Geochemistry, 6 in Stratigraphy-Paleontology, 6 in Petrology-Geochronology, 7 in Quaternary Geology and Volcanism, 3 in Marine Geology and Geophysics, 2 in Hydrogeology, 7 in Hydrology, 6 in Seismic Engineering and 2 in Engineering Geology.

The number of researchers in most groups is minimal enabling them to maintain research at a good level but not to expand it. Some groups such as those in Paleontology-Stratigraphy, Hydrogeology and Marine Geology and Geophysics are very deficient in number of researchers and, in the latter case, also in research projects, equipment and infrastructure.

Research projects developed during the period 1986-1992 amounted to 120; 66 of which were financed by the Fondo Nacional de Ciencia y Tecnología (FONDECYT) and the remaining 54 by other national and foreign institutions. Organisms with the highest number of FONDECYT-funded projects are Universidad de Chile (42), Universidad de Concepción (7) and Servicio Nacional de Geología y Minería (7) which account for 63.6%, 10.6 and 10.6%, respectively, of the total.

During the same period, 583 scientific publications were generated by the Universidad de Chile (70.2%), SERNAGEOMIN (19.5%), the Universidad Católica del Norte (5.8%) and the Universidad de Concepción (4.5%). These, plus 22 papers published by professionals from other centers, make a total of 605 publications during the period. They correspond to articles published in national and international journals and complete presentations published in the proceedings of international and national congresses. This total productivity distributed among 115 researchers indicates the generation of 0.9 publications a year per person, which is an adequate ratio. However, taking into account that publications in international journals amount to approximately 30% of the total, international productivity per person is reduced to 0.3 papers per year and this needs to be improved.

As compared to previous periods, productivity in the different disciplines of Earth Sciences has increased significantly. From 8.5 publications per year produced by the Instituto de Investigaciones Geológicas (IIG) in the period 1957-1975 and 6 in the period 1976-1980, productivity in the last 6 years increased to 19 publications per year in SERNAGEOMIN, its successor. At Universidad de Chile, the other major center of research in Earth Sciences, there was a change from an average of 3 publications per year until 1976, to an average of 20 in the period 1976-1980 and to 44 per year in the last 6 years. Productivity in some specific areas has been specially important; this is the case of Geophysics, in which the number of publications per year increased from 13 in the period 1976-1980 to 23 in the last 6 years. This is, no doubt, the result of an increased number of researchers and of the gradual development of the different disciplines.

Graduate programs in Earth Sciences are offered only by Universidad de Chile; these lead to a Doctor degree in Geology and to Master degrees in Geology or Geophysics. They were created in 1968 and 1975, respectively, and were intended to develop new human resources for research. However, besides 5 Latinamerican students who followed and obtained their Doctor degree in Geology under special grants given by the Organization of American States (OAS) and who have returned to their countries of origin, no Chilean student has received that degree, although at the present time there are four students enrolled in the program. Of 16 students registered for the Master degree in Geology since 1977, only 8 have completed the program and have received their degrees. As for the Master in Geophysics, 22 students have received the degree. Only a few of these are now engaged in research.

The above demonstrates the scarce interest of Chilean students to undertake graduate studies; this is mostly conditioned by the fact that students, although qualified and interested in research, do not have economic facilities to afford a graduate program nor do they have access to permanent positions in research centers. Under these conditions and

due to the great demand of professionals, specially in Geology and Geophysics, and the far better salaries that industry offers, they are easily attracted to go into professional rather than into academic activities. Graduate centers at the University cannot compete and thus they lose the opportunity to retain the talents that are needed, within the very short term, to reinforce the present research groups and to guarantee their continuity. This stands as an urgent problem that should be solved through a well funded scholarship program allowing graduate students to complete their studies without economic constraints. However, this implies that new and permanent research positions must be opened at the universities, specially now that the private sectors are not interested in using these capabilities, except for professional work.

Factors that in the near future may seriously hinder a sustainable development of the different disciplines in Earth Sciences are the migration of established researchers to professional work in industry, attracted by better salaries and the growing tendency of research centers to get involved in service contracts to improve their funding. A national effort must be done to overcome this situation.

Despite the above, considerable progress in various areas of Earth Sciences has been made during the last six years, especially in

Volcanism, Quaternary Geology Petrology-Geochronology, Seismology,

Atmospheric Sciences and Metallogenesis. Research has been done at a good level incorporating international participation through cooperative programs and projects with institutions and individual scientists. These programs have also facilitated the access to laboratories and equipments not yet available in the country but that should be incorporated into the national infrastructure.

However, fundamental areas like Paleontology-Stratigraphy, Hydrogeology and Marine Geology and Geophysics remain deficient both in number of scientists and research projects and, in the latter, in equipment and infrastructure. Young scientists should be trained through a program of postgraduate scholarships in prestigious centers of developed countries. Marine Sciences are obviously underdeveloped in their different disciplines, including Geology and Geophysics; the efforts that Universidad de Chile is making through an interdisciplinary Development Program should be given special consideration and support. This requires the acquisition of equipment and the generation of a special fund to finance the operation of research vessels which the Chilean navy and other institutions can provide.

Working in marine science in the country, it also involves the acquisition of the basic training programs achieved over the last 10 years and recommends procedures for future development.

1. HISTORICAL BACKGROUND

The scientific study of the Chilean territory was initiated more than 200 years ago. At first, scientific advance depended almost entirely on foreign scientific expeditions and explorations. Later, the establishment of a marine scientific center in the country allowed for a gradual development of the studies. In 1913, the Universidad de Chile founded the first scientific Institute for Biology, Marine and Meteorology, plus facilities for oceanographic studies in 1918. By 1952, the system comprised all marine sciences included 181 scientific personnel divided in 23 research groups spread in 12 geographic areas of the country. The marine scientific production was 0.3 articles per year per Chilean postgraduate training was provided at that time in the country, mainly through several 1-year programs in biology, and programs leading to a degree in marine biology and research in oceanography. The only postgraduate training opportunities in areas related to marine science (e.g., marine biology) were M.Sc. programs in biology.

2. PRESENT DISTRIBUTION OF THE SCIENTIFIC CAPACITY

At present, the scientific training in marine sciences in Chile includes about 100

Chapter V

MARINE SCIENCES

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A diversity of scientific disciplines (e.g., biology, physics, chemistry, geology) are involved in the scientific understanding of the marine environment. The need for diversified yet integrated knowledge, the different scales involved in the scientific study of the sea, the cost of equipment and other study facilities, all point to the importance of scientific collaboration and a balanced development of the various areas. This study summarizes the historical development of these various disciplines in Chile, compares their relative balance, describes the patterns of distribution, productivity and capacity to gather research resources of the scientific groups working in marine sciences in the country. It also evaluates the advances in the local training programs achieved over the last 10 years and recommends priorities for future developments.

1. HISTORICAL BACKGROUND

The scientific study of the Chilean marine environment started over 200 years ago. At first, scientific advance depended almost entirely on foreign scientific expeditions and explorations. Later, the establishment of resident scientists in the country allowed for a gradual diversification of the studies. In 1945, the Universidad de Chile founded the first institution (Estación de Biología Marina en Montemar) fully devoted to oceanographic studies in Chile. By 1982, the Chilean community of marine scientists included 184 full-time positions distributed in 23 research centers located in 12 geographic areas of the

country. The average scientific productivity was 0.2 articles/person/year. Only pre-graduate training was provided at that time in the country, mostly through several Licenciature programs in biology, one program leading to a degree in marine biology and another in oceanography. The only postgraduate training opportunities in areas related to marine sciences (e.g., marine biology) were M.Sc. programs in biology.

2. PRESENT DISTRIBUTION OF THE SCIENTIFIC CAPACITY

At present, the scientific community in marine sciences in Chile includes about 420

scientists that have either developed research projects or published in marine sciences in the last 5 years. They are distributed in 33 Institutions, but 8 to 10 private companies should be added to the list. The research results of these companies generally are of restricted distribution and therefore are not included in the common database systems used in this study.

A total of 622 publications in marine sciences were produced in Chile over the last 5 years. Distribution of authors as a function of the number of articles is notoriously skewed. Only 25% of the total number of researchers has produced 3 or more publications in the five year study period considered. Indeed, if only the most productive extreme is considered, it is found that 1.2% of the scientists have produced 25% of the total number of publications in the period. Likewise, even though 33 institutions in the country claim to be active in marine research, about 51% of the scientific production comes from only 4 of these institutions. Close to 80% of the grants approved by the most competitive granting agency in the country (FONDECYT) are awarded to less than 5% of the total number of institutions. It is evident, therefore, that most of the Chilean scientific capacity in marine sciences is restricted to a few institutions housing most of the active researchers.

3. RELATIVE DEVELOPMENT OF THE VARIOUS DISCIPLINES

Over 50% of the articles produced in the country in the last five years are in the areas of marine biology and biological oceanography. Aquaculture, fisheries and stock assessment are next in numerical importance. Other areas of oceanography are minimally represented. The number of physical oceanographers in the whole country is less than 25 while the number of chemical and geological oceanographers is less than 10. This is in spite of the numerous unresolved problems and potential developments which are specially significant for Chile. These problems include, for example, the El Niño/Southern Oscillation phenomenon, global change, plate tectonics, off-shore mineral and oil ex-

ploitation, pollution and environmental impacts.

Even though biological oceanography is the most developed discipline in the country, its coverage is clearly heterogeneous. Temporal and spatial patterns of many kinds of marine organisms are unknown; there are large coastal areas lacking studies on structure and organization of marine communities. The problem of biodiversity remains virtually untouched in our marine systems while the ecological effects of natural catastrophes is just starting to be understood. In addition, there are serious gaps in our knowledge on patterns of biological production and energy transfer.

The development of the more applied areas of marine science in Chile also exhibit deficiencies. In general there is a lack of coordination between the more basic and the more applied science which is required for resource management. The number of experts in aquaculture and especially in pathology is extremely limited. The basic biological knowledge of potentially economically important species requires much additional work. The number of studies on pollution and environmental impact of the marine systems has increased in the last years, but many such studies are part of the gray literature.

4. TRAINING IN MARINE SCIENCES

Even though in the last 10 years there has been a notorious increase in the number of pre and postgraduate programs, most of the formal training in marine sciences in Chile is at the pregraduate level and heavily oriented to marine biology. At present there are 14 licenciature programs, 4 M.Sc. programs and 5 Ph.D. programs related to marine sciences allowing for specialization in biological oceanography, coastal ecology or taxonomy.

5. AVAILABILITY OF RESOURCES

There are clear needs of more oceanographic ships and larger operational budgets for them. A larger number of marine reserves is also required. Laboratory infrastructure and equipment, libraries and computer networks are clearly limiting in many institutions. Since many of the most significant and scientifically most interesting events in the marine en-

vironment are low frequency/high intensity phenomena, the presently accepted pattern of allocating research resources on the basis of short-term research projects is limiting.

6. RECOMMENDATION

A diversity of actions should be initiated to increase the research capacity in marine sciences in Chile. Special efforts should be made to train and develop research activities in physical, chemical and geological oceanography. Due to the strong human

intervention on marine environment of the Chilean coasts, there are urgent needs to study biodiversity, community structure and organization of the commonest types of coastal communities throughout Chile. The increasing importance of aquaculture calls for the development of new cultivation technologies and training of new researchers in badly needed areas such as pathology, animal husbandry and hatchery. Similar needs apply to the areas of marine pollution and environmental impact.

A comparison of the present state of Physics in Chile with the situation existing in 1942 shows an important qualitative change. In several aspects the number of papers published in ISI journals in the decade 1982-1991 exceeds the total amount of publications during the whole previous history. Nowadays there is a significant number of students pursuing their Ph.D. studies either at the Universidad de Chile or at the Pontificia Universidad Católica de Chile. Moreover, the M.S. degree is offered by several universities across the country. The qualitative change developed over such a short period may be understood in view of the following happy consequences:

1. Return of a number of Chilean physicists who had left the country in the preceding decade.

2. Incorporation of several young Chilean physicists belonging to a second generation who had obtained their M.S. degree in Chile and afterwards followed their Ph.D. studies in universities of the U.S.A. and Europe.

3. Availability of science grants to young research persons. They are offered mainly by non-governmental institutions especially by the Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT), Program of the President Under patron of Universidad de Chile, and the FUNDACIÓN ASTRON. Recently the range of these institutions has

extended to support Ph.D. research programs in Chile.

4. Meeting every two years starting in December 1974, of the Golden Symposium of Physics, which have been a considerable nucleus in building the interest in Chile of a number of outstanding Chilean physicists living abroad. The symposia has also been of great usefulness for several authors who have the opportunity of presenting their work in the context of their own colleagues.

5. Foundation of the Summer Institute of Physics at the Universidad Austral de Chile in Valdivia. This Institute has been meeting regularly since 1977. So far 34 University

Chapter VI

PHYSICAL SCIENCES

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A comparison of the present status of Physics in Chile with the situation existing in 1982 shows an important qualitative change. In several sectors the number of papers published in ISI journals in the decade 1982-1991 exceeds the total amount of publications during the whole previous history. Nowadays there is a significant number of students pursuing their Ph.D. studies either at the Universidad de Chile or at the Pontificia Universidad Católica de Chile. Moreover, the M.S. degree is offered by several universities across the country. This qualitative change developed over such a short period may be understood in view of the following happy circumstances:

1. Return of a number of chilean physicists who had left the country in the preceding decade.

2. Incorporation of several young chilean physicists belonging to a second generation who first obtained their M.S. degree in Chile and afterwards followed their Ph.D. studies in top centers of the U.S.A. and Europe.

3. Availability of science grants to sponsor research projects. They are offered mainly by non university institutions especially by the Fondo Nacional de Ciencia y Tecnología (FONDECYT), Programa de las Naciones Unidas para el Desarrollo (PNUD) and the FUNDACION ANDES. Recently the range of their contribution has

extended to support Ph.D. fellowship programs in Chile.

4. Meetings every two years, starting in December 1978, of the Chilean Symposium of Physics, which have been a condensation nucleus to facilitate the insertion in Chile of a number of outstanding chilean physicists living abroad. This symposia has also been of great usefulness for advanced students who have the opportunity of presenting their thesis work to the criticism of their senior colleagues.

5. Foundation of the Summer Institute of Physics at the Universidad Austral de Chile in Valdivia. This Institute has been running steadily since 1977. So far 34 University

teachers have got a Master Degree in Physics at this institution.

6. Foundation of the Centro de Estudios Científicos de Santiago (CECS). This is a private institution which supports the research work of a number of physicists from Chile and abroad. Besides, this centre organizes periodically high level seminars and conferences on Particle Physics and Gravitation.

7. Establishment of research groups in several universities of Santiago and other cities, mainly in the areas of Solid State Physics, Particle Physics, Biophysics and Gravitation.

8. Consolidation and development of experimental groups, thoroughly committed to basic science research as well as to its potential applications. These groups are funded by science grants from the Fundación Andes and FONDECYT. They cover the topics of Solid State Physics, Materials Science, Biophysics, and Plasma Physics.

9. Lastly, we acknowledge with satisfaction the establishment during the past decade of several experimental groups which have been putting their ideas to work on the field of Applied Physics. An outstanding example is the group working with the Isochronous Cyclotron at the Facultad de Ciencias of the Universidad de Chile. There, the research staff has developed a method which uses certain nuclear reactions to explore the carbon and nitrogen contents of seeds. Besides, they use characteristic X-radiation obtained by particle bombardment to analyze the composition of atmospheric aerosols, ceramics, precolumbian skeletons, volcanic dust, and biological samples.

In the year 1982 Theoretical Physics in Chile had already experienced a significant revival thanks to the return of a considerable number of physicists who had emigrated during the preceding decade. In addition, a number of young physicists has been incorporated after obtaining their Ph.D. in USA and Europe. During the past decade this tendency has maintained and consolidated. The most significant change has been the strengthening of Ph.D. programs at the

Universidad de Chile and at the Pontificia Universidad Católica de Chile. A key role for this achievement is the establishment of Programs of Doctorate Fellowships by the Fundación Andes and FONDECYT.

These programs makes possible that the best graduate students spend in our country their most productive and active years.

Nowadays the main lines of theoretical physics research are developed in Chile at an international level. Part of the credit for this accomplishment goes to FONDECYT and the Fundación Andes for their financial support of basic research.

In contrast with the accelerated development of Theoretical Physics in Chile, Experimental Physics has subsisted with great difficulty in the few laboratories that are in condition to do research at an international level. In 1989 a group of experimental physicists summarized the reasons for this situation as follows:

"In our country experimental physics exhibits a degree of development considerably below that of theoretical physics. This circumstance is rather anomalous since physics is a natural science and, therefore, is based on experiments, either to confront models or to generate new hypothesis. It is well known that in countries more developed in science, the number of experimental physicists exceeds by large the one of theoretical physicists. When we make an estimate of the present status of experimental physics in Chile, we realize that the causes of its modest development are the absence of a 'critical mass' of researchers and the lack of modern facilities to allow a competitive work. There are several reasons that explain this anomaly, the most important are:

- Lack of a long term planning to organize the evolution of human and material resources required for experimental research. As a consequence of this fact important investments in infrastructure performed in the past were not steadily supported to keep the equipment running, as well as for maintenance and replacement. Under these conditions it usually happened that after a few years the equipment was no longer adequate

to perform research in up to date subjects under competitive conditions.

- Emigration of qualified personnel and lack of stimuli to insert new researchers. Several reasons have contributed to the exodus of senior researchers, subtracting their contribution to scientific work as well as to the training of new researchers. Moreover, to a graduate student it is usually more attractive to carry out a thesis in theoretical physics, where he can find more qualified advisors and "computational facilities, than embracing an experimental problem, where he takes the risk of suffering long delays owing to budget squeeze and poor maintainance.

- Dispersion of experimental work. The lack of planning has been responsible for the inhomogeneous development of different research lines. This fact implies a dispersion of efforts and hinders the interaction of experimental groups. In spite of this reality, one foresees a clear purpose to develop cooperative and cross-disciplinary research, a fact that shows certain degree of growth and maturity among the existent groups.

- Lack of demand from the industrial sector for innovative high technology. This fact implies an absence of stimuli from this sector to invest in basic and applied research, leaving to the State the bulk part of the investment in Research and Development, thereby restricting the available resources.

A survey of the number of active physicists in Chile gives a figure close to one hundred, out of which about a quarter performs experimental work. The ideal proportion should be five times as many experimental researchers as theoretical ones. This is the usual situation in developed countries, and close to the proportion in some countries of our region such as Brazil and Argentina."

FINAL REMARKS

Over the last three years the activity in Experimental Physics in Chile has shown signs of recovery, mainly due to the valuable

support of Fundación Andes and FONDECYT. The favoured areas have been Solid State Physics, Materials Science and Plasma Physics. They possess modern capital equipment and have incorporated a number of high level new researchers.

Concerning Theoretical Physics, the most serious problem which has emerged in the last years is the saturation of available positions in our universities. There are many outstanding chilean physicists in North America and Europe, with several years of post doctoral experience, who want to return to Chile. However, they cannot come back because there are no new openings in our universities for them. This fact is disappointing since the total number of active chilean physicists is only about one hundred.

ADDENDUM

MATHEMATICAL PHYSICS

Summary

If we define Matemathical Physicists as those who publish regularly in Journals like Communications in, Letters in, Journal of and Reviews in Mathematical Physics, there are at least six people in this area. Research is done in problems arising from: Schrödinger Operators, Atomic Physics, Symmetry and Conservation Laws, Integrable Systems, Fluid Mechanics, etc.

NON-LINEAR PHYSICS

Summary

Non-linear physics has had a booming development in Chile during the last decade, emerging as the third most important area of physics, when measured by the number of scientists who devote to it, partially or totally, their research time. In fact, 22 physicists have made contributions to the field, authoring around 100 papers. They work in five universities spread over the country, but mainly located near Santiago. The subject is attacked with a variety of approaches and techniques, which go from rather rigorous mathematics to computer experiments.

Chapter VII

MATHEMATICAL SCIENCES

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Rubí Rodríguez (Coordinator)

A picture of Chilean Mathematics research is given through seven sections covering its history, training—at both undergraduate and graduate levels—as well as an updated account of main fields to which Chilean original contributions are devoted. As a conclusion, the report ends with several recommendations to improve the development of Mathematics in the country.

1. HISTORICAL NOTES

As in all other countries of Latin America, Mathematics research in Chile starts in the 20th century. A predecessor of the Chilean Mathematical School is Professor Roberto Frucht, who reached the country in 1938. However, official recognition of the importance of Mathematics research did not come until 1957 when the Centro de Investigaciones Matemáticas of the Universidad de Chile was established by its Rector Juan Gómez Millas. A number of European mathematicians were hired for the Centre and the training of the first generation of young mathematicians followed. Most of the students of the Centre came from other fields of study, especially engineering and education. Soon, during the sixties, under-

graduate programs in Mathematics were created (Universidad de Concepción: 1963; Universidad Católica de Chile: 1964; Universidad de Chile: 1965), leading to the Licenciatura degree. About the same time the career of Mathematical Engineering was created at Universidad de Chile, with emphasis in Applied Mathematics.

In the sixties, Master degrees in Statistics and in Mathematics were respectively offered by the Centro Interamericano de Enseñanza de la Estadística and by the Universidad Técnica del Estado. Their main aim was rather a massive improvement of basic scientific training, than the development of research skills for students that would later continue their training at the doctoral level.

Other graduate programs in Mathematics began at the turning of the seventies with Magister programs in several universities: Universidad de Chile, Católica de Chile, Católica de Valparaíso, Concepción and Universidad Técnica del Estado. They were followed later by similar programs in the Universidad Técnica Federico Santa María and Universidad Católica del Norte. In addition, a Magister degree in Statistics were established at Universidad de Antofagasta, de Concepción, Católica de Valparaíso, and Universidad Católica de Chile during the seventies and the eighties.

Universidad de Chile formally started a Doctoral Program in 1968, although in practice no student had obtained the degree before the late eighties. Universidad Católica de Chile started its Doctoral Program in 1972, which has had the largest number of graduates, the first one in 1975. Recently, the Department of Mathematical Engineering of the Universidad de Chile started a Doctoral Program on Engineering Sciences, with major in Mathematical Modelling.

The majority of Chilean mathematicians obtained their doctoral degrees abroad: in USA, in Europe (mainly in France) or in Brazil, during the last three decades. As a result, before 1967 almost all university courses in Mathematics were not given by

active researchers. This situation is still prevalent in most universities, in spite of the good level attained by Mathematics research in the country.

Scientific societies have also had a significant impact in promoting the development of research in the Mathematical sciences.

The Chilean Mathematical Society (Sociedad de Matemática de Chile) was founded in 1970, though it obtained a legal status only in 1982. The Society is affiliated to the International Mathematical Union and two of its main contributions have been the organization of scientific meetings and the publication of two mathematical journals.

In addition the Society has elaborated National Research Programs, obtained special funding from United Nations for Mathematics research, supported international exchange agreements, established a National Mathematics Contest (Mathematics Olympiads) for school students.

The Chilean Statistical Society (Sociedad Chilena de Estadística) was founded in 1977 and it is affiliated to the International Statistical Institute. It publishes a journal, organizes national and regional meetings, and co-organizes international meetings with other Latinamerican societies in Statistics.

2. PRESENT RESEARCH IN THE MATHEMATICAL SCIENCES

A) HUMAN RESOURCES

The universe of scholars playing an active role in Mathematics research in Chile contains at most 140 people. Of these, 93 qualified to be included in the Directory of Scientists because of their productivity (criteria for inclusion in the directory were at least two publications reviewed in Mathematical Reviews and participation in a research project, in the last five years). Young mathematicians who have recently completed their Ph.D. constitute many of the rest of the

mentioned universe. Of these active mathematicians, 95% have a full-time position in Universities. A large percentage (57.3%) has a huge teaching load (over 15 hours per week). Despite this fact, 72% claim to devote at least 20 hours per week to research. 60% of researchers work in two research fields simultaneously. Nearly half of the researches have regular international contacts with experts in their field. Salaries are highly variable between institutions, but they roughly range from the equivalent of

US\$ 1,000 (beginners) to the equivalent of US\$ 2,000 (Full Professor).

B) MAIN RESEARCH FIELDS

Main fields to which Chilean mathematicians contribute are the following. In parentheses we mention the number of researchers who qualified for the Science Directory, according to the criteria indicated above: Algebra (10), Functional Analysis (6), Numerical Analysis (7), Combinatorics and Finite Geometry (3), Ordinary Differential Equations (5), Partial Differential Equations (11), Statistics (5), Complex Geometry and Analysis (6), Theoretical Computer Sciences (4), Logic and Foundations of Mathematics (5), Optimization and Operations Research (7), Dynamical Systems (14), Probability Theory and Stochastic Processes (6), and other fields of Mathematical Physics (4).

C) RESEARCH GROUPS

For the growth of Chilean research in Mathematics it seems fundamental to increase the interaction between the researchers in the same field. This is accomplished in part by the activities of national research groups. At present, seven such groups have been detected: Non Associative Algebras, Stochastic Analysis and Mathematica Physics, Complex Geometry, Logic and Foundations of Mathematics, Optimization, Group Representation, Dynamical Systems. All these groups have regular seminar activities, joint research projects, a good level and rhythm of publication in their fields, they collaborate in graduate programs and organize international scientific meetings. There are, of course, talented individual researchers and groups of a more informal character, who choose not to form part of any national group, but are personally involved in many of the same activities. They also should be supported.

3. MATHEMATICS TRAINING

There are, at present, several training programs in the country at different levels. The first degree, Licenciatura, exists in the Universidad de Chile, Santiago de Chile, Católica de Chile, Concepción, Técnica Federico Santa María, Católica de Valparaíso, de la Frontera and Católica del Norte. The degree is obtained after four-year training period and is sufficient for teaching at a secondary school level. There are also undergraduate programs in Statistics, having a more professional orientation. In any case, few of the students in these programs continue studying in a graduate program.

There is in addition the professional degree of Ingeniero Civil Matemático, given by University of Chile, after a six-year program, of which a significant fraction continue in doctoral programs in the mathematical sciences.

The first postgraduate university degree is the Magister in Mathematics. A program of the kind exists in the Universidad de Chile, Católica de Chile, Antofagasta, Católica de

Valparaíso, Católica del Norte, Técnica Federico Santa María, Concepción, Santiago de Chile. The aim of this academic degree has evolved during time. At first, its purpose was to initiate students in research, because of the lack of doctoral programs. At present the Magister provides an intermediate step in graduate training which is usually followed by doctoral studies, either in Chile or abroad.

There are also Magister programs in Statistics given by Universidad de Antofagasta, de Concepción, Católica de Valparaíso, and Universidad Católica de Chile. The levels and aims of these programs are rather different, and it may be said that they have a mix of a professional and a research objectives.

The highest level is the degree of Doctor. There are three programs offering this degree. Two of them are offered by Universidad Católica de Chile and Universidad de Chile, under the name Doctor en Ciencias, mención Matemáticas. This last university offers also the degree of Doctor en Ciencias de la Ingeniería, mención Modelación Matemática.

4. RECOMMENDATIONS

The main aim of these recommendations is to indicate measures to develop original areas of research, which may be recognized as outstanding by the international mathematical community. To achieve this purpose the Committee recommends:

1) The government should be more involved in promoting the development of Sciences in general. In particular, a recognition of the role played by Scientific Societies in determining a National Policy of Scientific Development is necessary. In addition, the government should support long-term programs financed partly by international agencies, such as UNDP.

2) It is necessary to promote a substantial increase in the number of positions in Chilean universities. In addition, working conditions have to be improved as well as the level of salaries, which should attain international standards.

3) Universities should attempt to fill open positions only with personnel having a proper research training.

4) Complement other types of programs with support for the activities of national research groups.

5) Create a National Library of Mathematics containing a complete collection of all main research journals. In addition, a Basic Mathematics Library for regional centres should be established which should contain elementary references for undergraduate studies.

6) Maintain and increase the number and level of financial support of the fellowship programs for graduate studies existing today.

7) State funding for research should be strengthened and diversified.

8) There should be a national support to salaries of researchers, competitively assigned, in addition to university salaries.

9) Extend computational facilities to all main universities, so that computational research networks may work effectively.

10) Special funding is needed to cover travel expenses inside the country for mathematicians working in isolated regions.

11) Financial support for publishing proceedings of scientific events (there is no such support at present).

12) Fellowships are needed to attract a number of Latin American students to Chilean graduate programs. Both international organizations, such as the Organization of American States, as well as national institutions have an important role to play in this direction.

13) In connection with the recommendation above, it is important to obtain a good coordination and regulation of Latin American graduate programs. This is a task which concerns the scientific community itself.

14) Support of the Chilean Government to all programs that promote interest in the Mathematical Sciences, such as the Olimpiada Nacional de Matemática, as well as other programs created by the Chilean Mathematical Society for school teachers.

Chapter VIII

CHEMICAL SCIENCES

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Research in chemistry is mostly accomplished in the University system. State and private corporations publish very little of their results and therefore it is not possible to evaluate the state of the art in that sector.

There are about 300 higher education centers in Chile with a total of approximately 250,000 students, 53% of them belonging to the university system. Only a few of the nearly 60 universities have developed any significant program in chemistry. In the last decade, however, graduate programs in chemistry in the universities, have been strengthened and new professional degrees in this field have been created.

Historically, teaching and research in chemistry began in the first quarter of the XX century, mainly in the areas of analytical and organic chemistry. It was not until the second half of this century however that research began to gain importance. Several professional degrees were and are now granted by the university system: chemical engineering, pharmaceutical chemistry, biochemistry and chemistry. In the last quarter of this century, the degree of Licenciado in Chemistry was introduced, simultaneously with the development of graduate programs in chemistry in several universities. The licenciado was

designed to prepare the student for basic research rather than for a particular professional career. The emphasis of the original system on granting professional degrees and the rather low esteem that pure science merited, were some of the reasons for the slow development of chemistry. This has also resulted in the relatively low salaries for researchers and limited financial support for research projects.

Research in chemistry takes place in different areas of this branch of science and has reached a commendable development in fields such as physical-chemistry covering aspects of electrochemistry, photochemistry, spectroscopy, theoretical chemistry, reaction mechanisms polymer chemistry, etc. Organic chemistry together with chemistry of natural product also has reached a satisfying level, covering subjects like organic synthesis, polymers, reaction mechanism, etc. Coordination and metal-organic chemistry are the main subjects developed in the field of inorganic chemistry. Unfortunately analytical

chemistry has not progressed as expected and environmental chemistry is recently beginning to develop.

Research in chemistry started spontaneously without any previous institutional or governmental planning. This has brought a certain degree of redundancy both in regard to research subjects and to costly equipment among different universities. This has been a drawback in the development of this area and only lately individual scientists have been taking steps to coordinate activities and avoid costly duplications. At the institutional level, however, there continues to exist indifference to the problem. Equipment and major instruments are available in some campuses thanks to a Scientific Research Program (PLANDECYT) and most of the above

mentioned groups get special financing from the Chilean Scientific and Technological Research Fund (FONDECYT).

To visualize the state of the art regarding research in chemistry in Chile, we felt that it would be useful to summarize and quantify the "productivity" of the different research groups throughout the country. In our survey we covered 107 research groups in chemistry throughout the country including scientists who publish in ISI-recognized Journals (Institute for Scientific Information). There are 426 active members in these groups a few at the level of graduated students but the majority independent research scientists. The accompanying tables present briefly, information on the number of research groups, their publications and areas of specialization.

TABLE 1

Research groups in chemistry in eight Chilean universities and their productivity during the 1987-1992 period

Institution	Nº of teams	Nº of members	Papers published	Papers presented at official meetings	
				National	Foreign
U. de Chile	30	113	381	224	186
P. U. Católica	10	36	227	102	186
U. Concepción	16	55	222	225	251
U. de Santiago	11	55	187	111	193
U. Católica Valparaíso	6	24	95	77	88
U.T. F. Santa María	8	28	79	40	43
U. Austral	5	11	9	10	16
U. del Norte	3	15	27	32	22

TABLE 2

Papers published by the research groups of major universities during the 1987-1992 period

Area	Nº of teams	Nº of scientists	Papers published
Analytical Chemistry	8	29	71
Physical Chemistry	24	79	443
Inorganic Chemistry	13	53	187
Organic Chemistry	15	50	206
Chem. of Natural Products	12	46	162
Environmental Chemistry	6	26	33
Other fields of Chemistry	12	59	123
TOTAL	90	342	1,223

To conclude it is clear that research in chemistry in Chile is not sufficiently developed. Substantial support and incentives will be necessary to increase research capabilities commensurate with the development of the country. To this end, interest in science in general has to be stimulated. This has to start at the elementary school level and

be continued at high school by the introduction of adequate science programs and the preparation of excellent science teachers. Simultaneously, graduate programs in science, including chemistry, have to be strengthened and an effective interaction between the academic and the business community developed.

TEACHING OF SCIENCE AT ELEMENTARY AND HIGH SCHOOLS

The "curriculum programs" at elementary and high schools are considered to be well designed with clear learning goals to be achieved, and many are developed according to the latest teaching methods. However, research indicates that the quality of the teaching is not as good as it should be. The curriculum is not fully implemented, and the quality of the teaching is not as good as it should be. The curriculum is not fully implemented, and the quality of the teaching is not as good as it should be.

The lack of interest in science shown by high school students is observed when they take the University Entrance Examination (Prueba de Aptitud Académica), an entrance examination for college entrance. One of the subjects taken by the students is science, and the results show that the students are not interested in science. The results show that the students are not interested in science.

The results of the entrance examination show that the students are not interested in science. The results show that the students are not interested in science. The results show that the students are not interested in science. The results show that the students are not interested in science.

Chapter IX

UNDERGRADUATE STUDIES IN SCIENCE

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TEACHING OF SCIENCE TO UNDERGRADUATES IN CHILE

This is an analysis focused on both the strengths and weaknesses which exist in the instruction of science to Chilean students at Elementary Schools, High Schools (lycée) and Universities nationwide. Some aspects to be considered are: the teaching of science in the pre-university educational system of Chile, the student's interest in science, the nature of the Science Licentiate Programs ("Licenciatura en Ciencias") offered by the Chilean universities, employment opportunities for the licentiates, and other formative influences on the students of science.

TEACHING OF SCIENCE AT ELEMENTARY AND HIGH SCHOOLS

The "instruction programs" at elementary and high schools are considered to be well designed, with clear and precise goals to be achieved, and many are developed according to the latest teaching methods. However, about 140,000 students finishing high school every year are found to be unprepared for the University's demands and badly trained for the jobs offered by the market. The conclusion to be drawn therefore is that science has been poorly taught to high school

students. The responsibility for this situation is centered on deficiencies in the preparation of the science teachers that are not only unprepared to teach good science, but are also unable to encourage and interest students in science careers. Salaries for teachers are too low to allow a reasonable standard of living to full time teachers. In addition, regulations of the Ministerio de Educación allowed students to evade learning Chemistry and/or Physics (optative) for approximately 10 years, until December 1989.

The lack of interest in science shown by high school students is observed when they take the University Entrance Examination (Prueba de Aptitud Académica), an absolute requirement for college entrance. Only 3% of the students take the test on physics and chemistry. In any case, the skills exhibited by students in the Specific Knowledge Tests (Prueba de Conocimientos Específicos) is considered very poor.

Nevertheless, in this analysis, students from private schools are the exceptions to the rule. In fact, it is from private schools that most university students come. Two schools located in Santiago, the Instituto Nacional and Liceo Manuel de Salas, are the only high schools of the State or Municipal system that have an important number of their students

among the highest scores in the Academic Capacity Test.

DEFECTS OF THE PRE-UNIVERSITY EDUCATIONAL SYSTEM

Considering the rate of progress in scientific knowledge in recent years and the very rapid development of new technologies, it is obvious that it is a difficult task for teachers to keep track of these new discoveries and technologies. Therefore, to provide a good high school scientific education, teachers must constantly be informed and trained in recent development and new techniques. On the other hand, since progress in science can make knowledge obsolescent very quickly, the objectives for teaching future scientists should be to enforce the capacity to think and rationalize rather than to promote the system of learning by memorization.

A continuous education of teachers by formal courses would be a convenient way for the acquisition of information in the specific fields they teach. Unfortunately, teachers generally do not have enough time or interest to study or to enroll in courses to improve their levels in modern science. In fact, it has been observed that teachers prefer courses on general topics or on educational techniques.

To produce better students interested in science, high school teachers should be trained to stimulate student interest in permanent knowledge avoiding accumulation of transient information. To accomplish this goal it is considered essential that teachers should be trained in institutions that have acquired high standards of scientific research. It is also highly recommended that the salaries of teachers be raised in accordance with their critical social importance.

It is generally found that Chilean students show little interest in science, either for its own sake or as a future career. This is clearly related to the outdated teaching techniques, and in general, a lack of laboratory equipment to practice even simple experiments. All of these facts make the present teaching system sadly boring and obsolete. This situation is in dramatic contrast with the availability of computers and video games, owned or rented

by youngsters at home, which present exciting and diverse simulations. It is unfortunate that computers and video systems are rarely used in teaching programs.

SCIENCE LICENTIATE PROGRAMS AT CHILEAN UNIVERSITIES

Under Chilean university regulations, the Licentiate degree is a requirement to pursue a Master or Ph.D. program. Until 1981, most Licentiate programs in Basic Sciences lasted a minimum of 12 semesters in the Chilean universities. In this 6 years period, an experimental thesis was included. Students who finished this program successfully were considered well-trained and prepared for a graduate program. This situation has changed in many universities with the reduction of the licentiate programs from 12 to 8 semesters and do not do a research thesis. Therefore, students now spend four years either in a licentiate program of science or in a licentiate program which is required to obtain a professional degree. As a result, many students are accepted now to follow undergraduate programs of a scientific career, but these students may later enter a professional career such as medicine or pharmacy, if they wish.

For the present report, in order to obtain an overview of the licentiate programs at Chilean universities nationwide, the committees in charge of this analysis gathered information on the number of licentiate programs offered in Chile, on the number of students and appointments of the licentiates in the job market. The programs analyzed are biological sciences, marine biology, biochemistry, physics, chemistry and mathematics. As will be seen below, this analysis indicates that a wide variety of programs are in effect today in Chilean universities. For example, some licentiate programs of biology are closely associated to programs to obtain a teacher's degree in biology. Obviously, this represents a serious effort to improve the formation of high school teachers. The diversity of programs (see the following tables) make a very difficult task to draw general conclusions about their quality or

predict how many of these students are aimed to a career in science.

At the Universidad Católica de Chile, students of science are accepted into a core program called Basic studies (Ciclo Básico), in which at termination, students may enter either the Faculty of Education (to become high school teachers) or any of the Faculties of Sciences (Biology, Chemistry, Physics and Mathematics).

The following table indicates the number of students enrolled at the licentiate programs in Science and the number of students graduated in the academic year 1991.

Science Licentiate Programs at Chilean Universities		
Programs	Enrollment 1991	Graduates 1991
Biochemistry	192	77
Biological Sciences	302	50
Marine Biology	240	22
Chemistry	307	52
Physics	164	16
Mathematics	335	39
Total	1,540	256

Biochemistry Licentiate Programs		
University	Enrollment 1991	Graduates 1991
Universidad de Chile	30	19
P. U. Católica de Chile	22	8
U. de Concepción	35	21
U. Católica de Valpo.	40	15
U. de Santiago	25	5
U. Austral de Chile	40	9
Total	192	77

Biological (CB) Sciences and Marine Biology (BM) Licentiate Programs			
University	Enrollment 1991	Graduates 1991	Program
U. de Chile	40	6	CB
*P. U. Católica de Chile	77	12	CB
+U. de Concepción	55	5	CB
+U. de Concepción	55	8	BM
U. Católica de Valpo.	60	13	CB
+U. Austral de Chile	30	2	CB
+U. Austral de Chile	40	6	BM
U. Católica del Norte	65	5	BM
U. de Valparaíso	30	0	BM
U. Católica de la Santísima Concepción	50	3	BM
U. de Talca	40	12	CB
Total	542	72	—

* Ciclo Básico de Biología - Basic Training in Biology.

+ Licenciatura más título profesional - Licentiate and Professional Degree.

CB = Ciencias Biológicas (o Biología) - Biological Sciences or Biology.

BM = Biología Marina - Marine Biology.

Chemistry Licentiate Programs		
University	Enrollment 1991	Graduates Class 1991
Universidad de Chile (1)	30	9
Universidad de Chile (2)	30	5
P. U. Católica de Chile (3)	77	23
U. de Concepción	30	4
U. T. F. Santa María	10	1
U. Católica de Valpo.	40	8
U. de Santiago	50	2
U. Católica del Norte	40	0
Total	307	52

(1) Facultad de Ciencias Químicas y Farmacéuticas.

(2) Facultad de Ciencias.

(3) Enrollment in a Basic Training Program (Ciclo Básico).

Physics Licentiate Programs		
University	Enrollment 1991	Graduates Class 1991
Universidad de Chile	25	4
P. U. Católica de Chile (1)	19	5
U. de Concepción	30	1
U. Téc. F. Santa María	10	2
U. Católica de Valpo.	30	4
U. de Santiago	50	0
Total	164	16

(1) Enrollment in a Basic Training Program (Ciclo Básico).

Mathematics Licentiate Programs		
University	Enrollment 1991	Graduates Class 1991
Universidad de Chile	30	3
P. U. Católica de Chile (1)	80	7
U. de Concepción	30	3
U. Téc. F. Santa María	10	1
U. Católica de Valpo.	45	16
U. de Santiago	50	0
U. Católica del Norte	60	9
U. de Valparaíso	30	0
Total	335	39

(1) Enrollment in a Basic Training Program (Ciclo Básico).

Chapter X

Ph. D. PROGRAMS IN SCIENCE

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1. HISTORICAL ACCOUNT

Science graduate programs are quite recent in Chile. The first regular doctoral programs at Chilean universities appeared during the 60's. Their creation was closely related to a deep process of changes undergone by the Chilean university system at that time, a process that also took place in most Latin American universities. One of the aims of that process was to establish the interest of the University system to not only train professionals but also academicians. Also, the academic staff increased their dedication to the University from part to full time.

Together with these advances, several specific programs of international cooperation were initiated, such as that of the Rockefeller

Foundation, the University of California, the Exeter University-Universidad Católica program, the DAAD-Universidad de Concepción program and the Humboldt fellowship program.

During the 60's several important institutions for the development of Chilean science were created: CONICYT, the Comisión Nacional de Investigación Científica y Tecnológica, in 1967, and the Faculties of Sciences of the Universidad de Chile and Universidad Católica de Chile, in 1968 and 1970, respectively. Also, in 1968 took place the Reforma Universitaria, a series of deep changes in the political system of the universities.

2. CHARACTERISTICS OF THE PROGRAMS

A. ACADEMIC REQUIREMENTS OF THE PROGRAMS

In Chile, as in most other Latin American countries, the graduate programs adopted the American model, i.e. a limited number of

obligatory courses and a doctoral thesis. All the programs have similar requirements.

Applicants to a graduate program in science must have a science licentiate or equivalent degree. The licentiate is usually a

4-5 year program. Equivalent studies are assessed by the direction of each program.

The program work is determined for each student by a Postgraduate Committee and it usually includes several courses, seminars, a doctoral thesis, a qualifying and a final examination.

The main activity is the thesis work. This work must be an original research and a contribution to a particular field of science. The thesis is supervised by a professor of the program, and although its duration is variable, it usually takes four to five years to be completed. The degree granted is that of Doctor with a mention in the particular scientific area of the program.

A. DYNAMICS OF THE PROGRAMS

Table 1 shows the year in which the first program in each scientific area was established in Chile, the number of students graduated so far, and the number of students currently enrolled.

As shown in Table 1, the doctoral programs in Biology are the oldest ones and globally, they have graduated more than 100 students and have an important number of students currently enrolled.

TABLE 1			
Scientific area	First year	Students graduated	Currently enrolled 1992
Biology	1955	116	140
Physics	1971	12	33
Geology	1968	5	3
Mathematics	1968	14	16
Chemistry	1968	100	88
Total		247	280

The first doctoral program in chemistry was established in 1968 and 100 students have graduated from such programs.

The programs in other sciences have a smaller number of graduate and enrolled students.

Table 2 shows the dynamics of the programs in terms of number of students entering the program, total number of students enrolled, and number of students graduated during each year.

TABLE 2																			
Dynamics of the programs, number of students initiated (I), registered (R) and graduates (G), in the period 1988 to 1992																			
Discipline	1988			1989			1990			1991			1992			Total			
	I	R	G	I	R	G	I	R	G	I	R	G	I	R	G	I	R	G	G
Biology	31	86	11	24	109	7	28	113	10	22	131	13	28	140	10	133	579	51	
Physics	2	6	1	5	17	2	8	21	1	7	26	2	9	33	0	31	103	6	
Geology	1	1	0	0	1	0	2	3	0	0	4	0	0	3	0	3	12	0	
Mathematics	0	1	2	4	5	2	1	4	1	2	6	3	3	16	0	3	12	8	
Chemistry	17	50	8	11	47	6	9	55	11	8	39	14	23	88	4	68	279	43	
Total	51	144	22	44	179	17	48	196	23	39	206	32	63	280	14	238	985	108	

The number of students who have obtained the doctoral degree is very low. The average number of doctors graduated is about 23 per year. This is really a major problem for the development of science in Chile.

The evaluation of these doctoral programs is a complex task, since there is not one single parameter on which to base it. Keeping this in mind, one possible parameter to use is the publications derived from doctoral theses. It is widely accepted that publication in international journals with editorial committee is a sensible measure of the originality and creativity of the research.

Table 3 shows the number of such publications in the different sciences.

As shown in this Table, Biology and Chemistry have an average of around 3 publications per thesis, while the numbers for Physics and Mathematics are around 2 and 1, respectively. Considering the nature of each science, the natural and exact sciences have a satisfactory international evaluation.

C. FINANCIAL SUPPORT

This is a very important aspect of the doctoral programs. The socio-economic situation of some graduate students is really critical and certainly inadequate for an optimal performance in the programs. For this reason the national scientific community is constantly demanding the creation of fellowship programs.

The recent creation of doctoral fellowship programs by Fundación Andes and CONICYT (in 1987 and 1988, respectively) has been a major factor in encouraging students to pursue their graduate training in Chile.

Prior to the creation of these fellowships programs, Fundación Andes requested a group of British scientists to evaluate the Chilean doctoral programs and to make recommendations on how to improve them. This assessment was followed by another, led by a group of U.S. scientists in collaboration with the Academia Chilena de Ciencias and the U.S. National Academy of Sciences. Such initiatives have shown the necessity to periodically evaluate the level and development of the graduate programs.

In 1988 CONICYT started its Doctoral Fellowship Program, which offers 30 fellowships a year (45 in 1992-1993). The average number of 2.5 applicants per available fellowship during 1988-1993 speaks of the scarce interest of students for doctoral training. While it is true that the low interest for scientific careers is an international problem, the case in Chile is far worse. Some of the factors that play a role in this situation are the poor quality of science education at the school level and the lack of interest of society at large in the natural and exact sciences.

More recently CONICYT has created new doctoral grants to help advanced graduate students to complete their theses.

TABLE 3			
Publications as product of the Doctoral Thesis			
Discipline	Nº thesis considered	Total publications	Average Publications/Thesis
Biology	70	235	3.3
Physics	12	28	2.3
Geology	5	0	0.0
Mathematics	14	14	1.0
Chemistry	77	239	3.1

3. CONCLUSIONS AND RECOMMENDATIONS

The number of students applying to graduate programs is low. The ratio of applicants to doctoral fellowships offered is 2.5 The lack of obligatory science courses at the secondary school level is an alarming omen for the future of scientific training and research in Chile.

There is an urgent need to substantially increase the degree of awareness and understanding by Chilean society of the importance of science and scientists for the development of the country.

On the other hand, graduate students generally ignore what their future job opportunities will be and do not seem to be aware of what their role in society might be.

Unfortunately, Chile has never had a clear and aggressive policy regarding graduate training programs. In spite of the already mentioned recent efforts by CONICYT and Fundación Andes, we begin to see a noticeable decline in the quantity and diversity of the scientific community. Probably the lack of clarity regarding the role of science in our country has led to the atrophy of the formative aspect. In general, the institutions of higher education have emphasized undergraduate training, leaving research and science graduate programs to their own fate.

This situation requires prompt measures to consolidate and stabilize the development of scientific research in Chile, which is directly related to the development of graduate training. Certainly the leading

research groups are mainly responsible for the quality of graduate training. Let us remember that all of the basic research and most of the applied research carried out in Chile is concentrated in a few faculties of the more traditional universities.

In Chile research centers with a “critical mass” of high quality researchers and appropriate infrastructure for graduate training are quite scarce. Therefore, we think that collaborative efforts between different research centers and universities are very important. So far such collaborations have been made by personal efforts of the researchers involved. It seems necessary to establish a system to encourage a fluid academic and student exchange between different graduate programs.

It is also important to mention that the fraction of academics belonging to graduate programs who actually have supervised or are supervising doctoral theses, is less than 50%, with the highest in Biology (48%), followed by Chemistry (30%) and only 20% in Physics. From this we can conclude that not all academics belonging to a graduate program are competent for the graduate training of students and that a proper selection system of academics should be established at this level. This point calls to rethink the design of the current graduate programs. However, it must be kept in mind for such analysis that we are not in a position to loose the few applicants currently interested in doctoral training in sciences.

Chapter XI

SCIENTIFIC PRODUCTIVITY

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Scientific productivity in Chile has been analyzed using a database containing information on all scientific publications originated in the country since 1985 and registered in the databank of the Institute of Scientific Information, ISI. Although for Chile this database is biased, e.g. while natural Sciences and Mathematics are under-represented Astronomy tends to be over-represented, it is the most objective source available for comparisons between disciplines and assessments of productivity in a regional, or worldwide context.

Fig. 1 shows the total output of publications on a yearly basis from 1980 to 1992. Chilean scientific output has grown rather steadily from 550 papers in 1980 to about 1350 in 1992.

The number of publications for each basic discipline is shown in Figure 2 for each two year period since 1983. Mathematics, Chemistry and Physics exhibit marked increases. For Biology and Astronomy the number of publications has remained stable, while in Earth Sciences, after increasing in 1985-1986, it has declined steadily since.

Figure 3 shows the percentage of total publications produced by each basic discipline for two periods, 1976-79 and 1990-91. The

contributions of Mathematics, Physics and Chemistry have grown from 0.5%, 2.1% and 6.9% to 4.1%, 5.9% and 14.2%, respectively. On the other hand, the contribution of Astronomy has remained rather constant at about 11%, while those of Biology and Earth Sciences have declined from 28.5% and 2.2% to 21.9% and 1.4%, respectively. These data illustrate the dynamics of development of the different sciences in Chile.

Table I shows the institutional origin of scientific publications in Chile for the period 1987-1991. Universities (U) account for almost 80% of the publications, and most of this scientific productivity is associated to only four universities (Universidad de Chile, Pontificia Universidad Católica de Chile, Universidad de Concepción and Universidad Austral de Chile contributed with 86.4% of the total publications in 1991).

The quality of the scientific research can be assessed by a variety of bibliometric techniques. This is certainly not the place to analyze the validity of those techniques (e.g., co-citation analysis) but a few have been used to assess the activity of Chilean science and the scientific impact of Chilean publications as compared to other countries. As shown in Table II, in 1984 Chile was active in 1,075

FIGURE 1

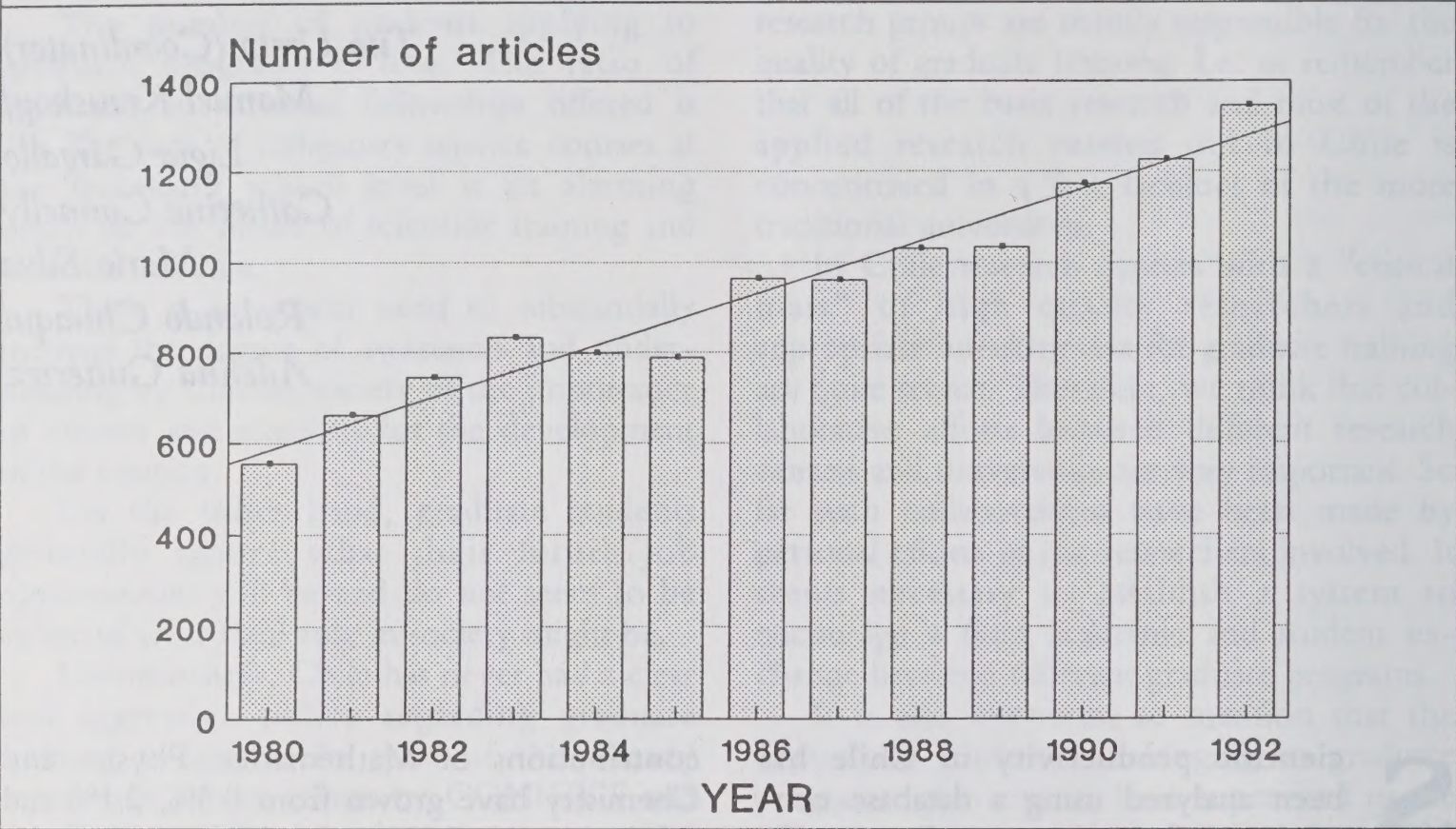


FIGURE 2

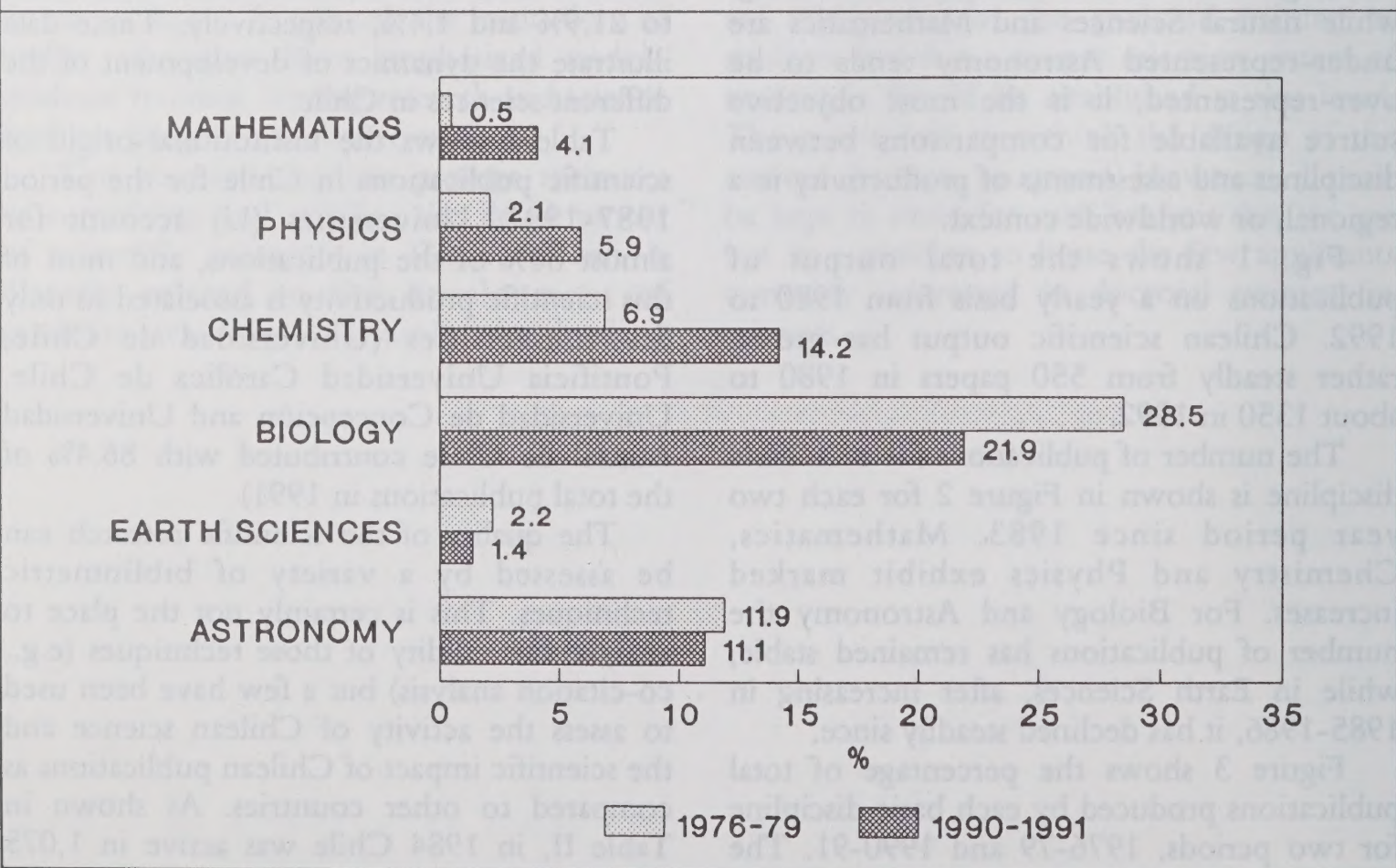
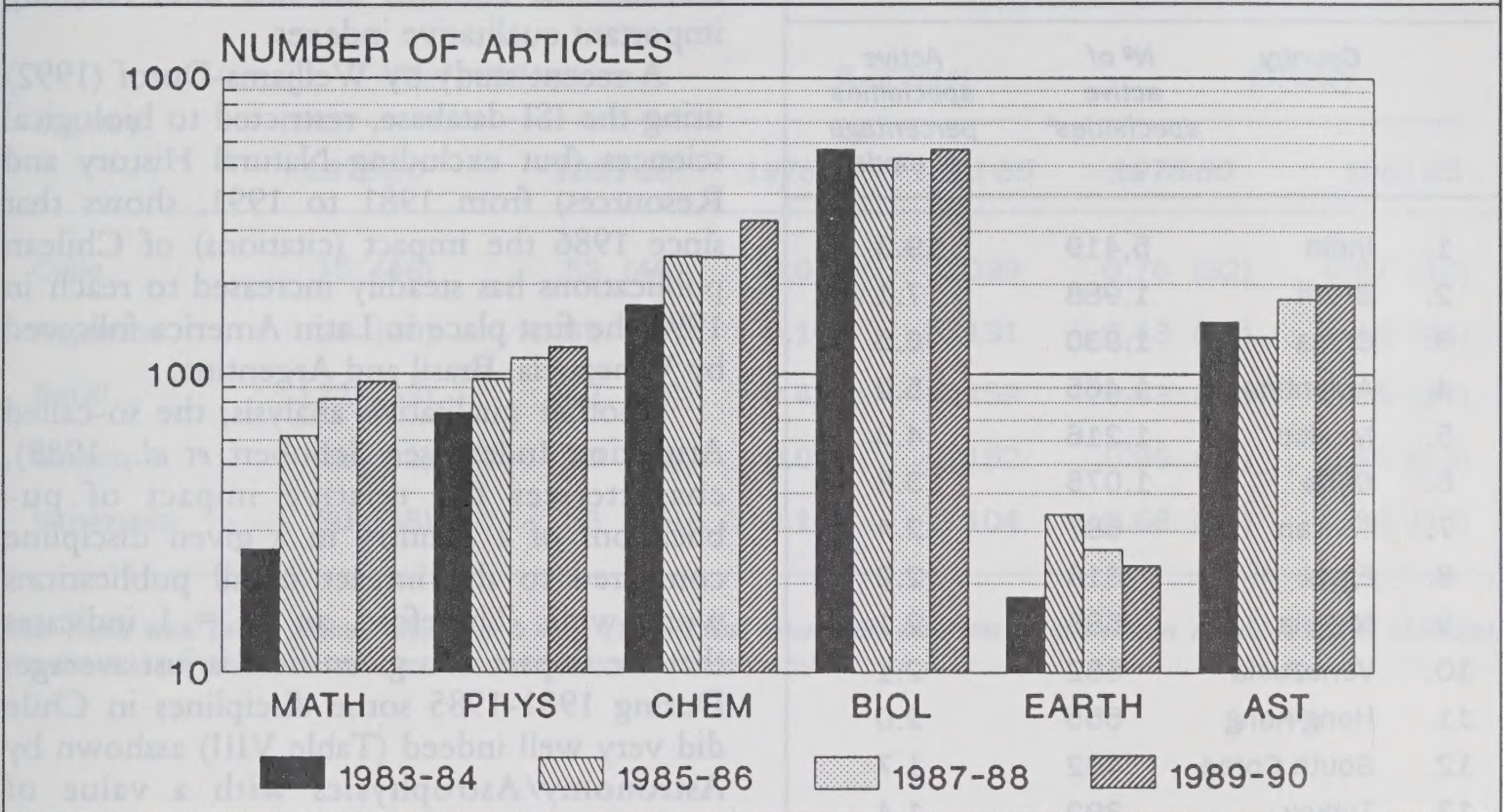


FIGURE 3



specialties, a 3.8% of the total of specialties distinguished by the model of the Center for Research Planning (CRP model). The same study shows that in 1984 Chile was internationally strong in 25 specialties, mainly in the biological and clinical fields. Table III shows the % of research topics of rapid development for the World, Latin America and Chile, estimated with the CRP model for data of 1985.

The observed citations/expected citations ratio (Braun *et al.*, 1985) assesses the impact of publications with reference to the nature of the communication channel used. An efficacy of 1 is average impact, more than 1 is higher than average, and less than 1 is lower than expected. Tables IV, V, VI and VII shows this index for the most productive Latin American countries, for 1978-80 and 1981-85, for Mathematics, Physics, Chemistry and Life Sciences.

Taking into account the number of inhabitants and the gross national product, Chilean scientific productivity is the highest

TABLE I		
Origin of Chilean articles between 1990-1991		
Institution	1990	1991
U. de Chile	450 (45.9)	479 (48.3)
P. U. Católica	210 (21.4)	241 (24.3)
U. de Concepción	69 (7.0)	62 (6.3)
U. Católica Valpo.	26 (2.7)	19 (1.9)
U.T. F. Sta. María	26 (2.7)	20 (2.0)
U. de Santiago	39 (4.0)	28 (2.8)
U. Austral	73 (7.4)	74 (7.5)
Total	893	923
Other universities	88 (5.4)	68 (6.8)
Other institutions	219 (18.7)	263 (21.5)
TOTAL	1,174	1,226

Figures in parentheses indicate percentage of total number of mainstream papers by all universities.
Other : Publications from other universities
TOTAL : The sum indicates the real participation of each university and does not necessarily coincide with the number of published articles.
Adapted from Krauskopf (1993).

TABLE II			
Development countries ranked by the number of specialties in which they are active			
Country		Nº of active specialties*	Active specialties percentage of model
1.	India	5,419	19.3
2.	Brazil	1,988	7.1
3.	China	1,830	6.5
4.	Argentina	1,465	5.2
5.	Mexico	1,216	4.3
6.	Chile	1,075	3.8
7.	Taiwan	687	2.4
8.	Egypt	618	2.2
9.	Nigeria	586	2.1
10.	Venezuela	582	2.1
11.	Hong-Kong	555	2.0
12.	South Korea	482	1.7
13.	Turkey	392	1.4
14.	Singapore	392	1.2

* Active specialties are those in which at least one paper by author from the country was published in 1984.

TABLE III			
Areas of fast development			
Area	World (%)	Latin America (%)	Chile (%)
Astronomy	11.6	11.4	12.7
Basic Biology*	13.8	4.6	8.3
General Biology**	4.2	2.2	2.8
Geosciences	4.7	3.7	8.6
Physics	17.6	11.6	8.5

* Essentially research in molecular, physiological or biomedical aspects.
** Mainly biological research about natural resources.

in Latin America. As to the dynamics of Chilean scientific contribution, it is found that Mathematics, Physics and Chemistry have increased their participation in the international context, the first ones reaching important qualitative indexes.

A recent study by Welljams-Dorof (1992) using the ISI database, restricted to biological sciences (but excluding Natural History and Resources) from 1981 to 1991, shows that since 1986 the impact (citations) of Chilean publications has steadily increased to reach in 1991 the first place in Latin America followed by Venezuela, Brasil and Argentina.

Another qualitative analysis, the so-called Attraction Index (see Schubert *et al.*, 1989), characterizes the relative impact of publications of a country in a given discipline compared to the impact of all publications world-wide. Therefore, an AI = 1 indicates that the impact of a given field is just average. During 1981-1985 some disciplines in Chile did very well indeed (Table VIII) as shown by Astronomy/Astrophysics with a value of 17.36, or Polymer Sciences (3.36) and Ecology (3.31). Thus, although the output of Chilean publications is rather low, they seem to be of interest since several of them have indexes significantly higher than 1.

In brief, for the period under consideration:

- Chilean scientific productivity has steadily increased. A major part of this productivity is associated to a few universities.
- In terms of disciplines, Mathematics and Physics show the strongest qualitative and quantitative growth; Chemistry has grown substantially but it has not increased its qualitative efficacy; Biological Sciences have not grown quantitatively but have increased their qualitative impact.
- Topics in Astronomy and Earth Sciences have a good position at the world level. Topics in Biological Sciences have an impact above the Latin American average.
- Scientific productivity in Chile has been the subject of several papers (see Brown *et al.*, 1991; Krauskopf, 1993; Krauskopf & Pessot, 1987; Krauskopf & Prat, 1990).

TABLE IV						
Mathematics						
Country	Nº of publications		% of total		Efficacy	
	1978-80	1981-85	1978-80	1981-85	1978-80	1981-85
Chile	15 (48)	52 (46)	0.052	0.099	0.76 (32)	0.97 (16)
Argentina	29 (40)	69 (42)	0.100	0.131	0.43 (48)	0.40 (44)
Brazil	121 (23)	242 (26)	0.420	0.459	0.63 (39)	0.66 (37)
Mexico	28 (41)	80 (38)	0.097	0.152	0.95 (22)	0.98 (13)
Venezuela	30 (38)	55 (45)	0.104	0.104	0.68 (34)	0.98 (12)

The Table was taken from Krauskopf & Prat (1990) and was built with data from Braun et al. (1987a) (1988a). Numbers in parentheses refer to the world rank of each country.

TABLE V						
Physics*						
Country	Nº of publications		% of total		Efficacy	
	1978-80	1981-85	1978-80	1981-85	1978-80	1981-85
Chile	153 (38)	410 (38)	0.085	0.105	0.95 (13)	1.03 (8)
Argentina	391 (32)	1,108 (31)	0.220	0.285	0.52 (47)	0.50 (40)
Brazil	963 (20)	1,981 (22)	0.530	0.510	0.53 (44)	0.52 (38)
Mexico	380 (34)	899 (34)	0.210	0.231	0.75 (28)	0.67 (28)
Venezuela	148 (39)	352 (42)	0.082	0.091	0.61 (38)	0.65 (30)

The Table was taken from Krauskopf & Prat (1990) and was built with data from Braun et al. (1987a) (1988a). Numbers in parentheses refer to the world rank of each country.

* Includes Physics and Space Sciences.

TABLE VI						
Chemistry						
Country	Nº of publications		% of total		Efficacy	
	1978-80	1981-85	1978-80	1981-85	1978-80	1981-85
Chile	127 (40)	307 (38)	0.081	0.116	0.75 (31)	0.64 (35)
Argentina	366 (32)	1,003 (24)	0.23	0.38	0.88 (24)	0.75 (29)
Brazil	379 (31)	623 (33)	0.24	0.23	0.68 (37)	0.64 (36)
Mexico	137 (38)	300 (39)	0.088	0.114	0.62 (44)	0.54 (45)
Venezuela	128 (39)	218 (42)	0.082	0.083	0.68 (38)	0.63 (38)

The Table was taken from Krauskopf & Prat (1990) and was built with data from Braun et al. (1987b) (1988b). Numbers in parentheses refer to the world rank of each country.

TABLE VII						
Life Sciences*						
Country	Nº of publications		% of total		Efficacy	
	1978-80	1981-85	1978-80	1981-85	1978-80	1981-85
Chile	1,108 (33)	2,092 (34)	0.18	0.18	0.76 (41)	0.66 (49)
Argentina	1,629 (29)	3,045 (28)	0.26	0.27	0.66 (55)	0.58 (62)
Brazil	2,167 (27)	3,937 (27)	0.35	0.34	0.64 (57)	0.61 (59)
Mexico	1,054 (34)	2,094 (33)	0.17	0.18	0.79 (36)	0.71 (39)
Venezuela	410 (41)	758 (41)	0.07	0.07	0.67 (53)	0.63 (55)

The Table was taken from Krauskopf & Prat (1990) and was built with data from Braun et al. (1987b) (1988b). Numbers in parentheses refer to the world rank of each country.

* Includes Biology, Biomedicine and Clinical Medicine.

TABLE VIII Cualitative Indicators of Chilean research, 1981-1985			
	Nº art.	%*	IA
Biochemistry and Molecular Biology	305	0.26	1.00
Biophysics	61	0.19	1.71
Botany	98	0.25	1.81
Citology and Histology	56	0.18	0.97
Ecology	55	0.46	3.31
Neurosciences	61	0.10	0.61
Farmacy and Pharmacology	111	0.14	0.81
Physical Sciences	386	0.10	1.61
Astronomy Astrophysics	177	0.78	17.36
Organic Chemistry	65	0.13	1.04
Physic-Chemistry	81	0.19	1.68
Polymer Sciences	60	0.28	3.36

* Indicates percentage with respect to the total publications (worlwide) during the period in the subdiscipline. See text for an explanation of IA. Adapted from Krauskopf (1993) using data from Schubert et al. (1989).

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Chapter XII

INTERNATIONAL SCIENTIFIC COOPERATION

*Luis Vargas (Coordinator) and
Jorge Allende*

BRIEF HISTORY

International scientific cooperation has been analyzed with particular reference to the financial aid received from the international community during two periods. The first period of significant support, between 1940 and 1960, was characterized by aid in the form of postgraduate fellowships from private foundations, exemplified by the Ford, Guggenheim and Kellogg Foundations of the USA. Shortly after, the Rockefeller Foundation initiated a program of support through the purchase of heavy equipment for basic research to be used in the research centers located in the medical faculties in Chile. Loans from the International Bank of Development also contributed strongly to the creation of basic scientific infrastructure in Chilean universities.

This initial stimulus was strengthened in the early 60's by the approval of a significant number of individual research grants for Chilean research groups by the National Institute of Health, the National Science Foundation and the Aid for International Development Programs of the United States Government.

During this same period, a project called The Plan Chile-California was initiated by the Ford Foundation which financed, over a 10 year period and at a cost of one million dollars per year, exchange programs between the University of California and the University of Chile in the areas of agronomy, biology and environmental science. The impact of this program was and is still valued both in relation to the development of basic sciences in Chile as well as on the level of expertise in

Chilean agriculture, which is evident from the present position of Chile in the international produce market.

A very significant drop in international financial support of Chilean science occurred in 1973, which lasted through 1989, and was related to the political situation caused by the military government of Chile. However, during the 1980's, multilateral support projects played an important role in maintaining scientific research and training in the country. Specially important were the UNDP research projects that strengthened basic sciences, and a subsequent UNDP project that emphasized applied research linked to the productive sector, as well as a project designed to upgrade scientific equipment in the universities.

In 1990, with the return of the country to a democratic system, there was a significant recovery of international support and this has continued to the present.

INTERNATIONAL COOPERATION IN THE TRAINING OF SCIENTISTS

Probably the most important international support for Chilean science has consisted in the training of scientists. Since Chilean doctoral programs in sciences only started functioning in the 70's and these programs have produced a very limited number of Ph.D.'s, the vast majority of Chilean scientists have been trained in other countries. Of a total of approximately 1500 scientists with doctor's degrees working in the country, a total of 1215 were trained outside of Chile, 684 of them receiving their degrees in Europe and 413 in the USA.

In addition to this very important doctoral training, international cooperation has provided and is still providing a large number of short-term fellowships and post-doctoral fellowships that are essential components of scientific human resource development in our country.

SUPPORT OF SCIENTIFIC PROJECTS BY FOREIGN GOVERNMENTS AND BY MULTILATERAL AGENCIES

International cooperation for science and technology is being received by Chile through bilateral agreements with a large number of countries.

Multilateral agencies are also providing some important support in this area. According to CPU (Corporation for University Promotion), 9.4% of the total 355 million dollars received by Chile in the period 1990-1992 in the form of bilateral and multilateral cooperation has been dedicated to science and technology.

Among the present major donors, special mention should be made of JICA of Japan, SAREC of Sweden, the European Community, agencies of the Governments of Spain, Italy, Germany and France, the US AID and the IDRC of Canada. The amounts provided by the UN agencies such as UNDP,

UNESCO, UNIDO and FAO are lower but their contributions are important for the linking of Chilean science to international programs. The Organization of American States plays a similar role at the regional level. The recent loans from the Interamerican Bank have also played an important role in the creation of instruments such as FONDEF (Fund for science and technology development) and FONTEC (designed to promote technological industrial research).

NON-GOVERNMENTAL AGENCIES

Many non-governmental international agencies are presently providing significant support to Chilean science. Although it is difficult to get information of all the different institutions that participate, a special mention should be made of the International Foundation for Science, an institution that has supported the research of a large number of younger Chilean scientists. The Third World Academy of Sciences also has been an institution that has made an important contribution to stimulate scientific activity in Chile.

SCIENTIST TO SCIENTIST COLLABORATION

The most important and fruitful scientific cooperation results from the joint work of two scientists, who have discovered that they have common interests and complementary capacities. Often such collaboration crosses national boundaries. Close to 20% of all Chilean scientific publications are co-authored by scientists living in foreign countries. This is an important percentage that has been increasing in recent years. Often this collaboration is supported by joint research grants obtained directly by the researchers. Accordingly, the amounts of funds received by Chilean laboratories have a level of approximately 18 million US dollars in 1991. This amount is higher than the total funds allotted that year by our national fund for science and technology (FONDECYT).

REGIONAL COLLABORATION

Chilean individual scientists, scientific societies and institutions have been very active

in efforts to promote regional integration in Latin America. An example of this is the Latin American Network in Biology (a member of the ICSU IBN) and the Network in Botany that are coordinated by Chilean scientists. Many Chilean laboratories participate in regional projects supported by UNESCO, OAS, FAO and other institutions. Recently the Chilean government initiated a program to provide 40 postgraduate training grants to Central America applicants.

INTERNATIONAL LINKS OF CHILEAN SCIENTIFIC SOCIETIES

All the major Chilean Scientific Societies are active members of regional and inter-

national associations. This international links have been very important to maintain Chilean science up-to-date in world development and to permit us to have a voice in international science. The National Committee for ICSU, organized under the leadership of the Chilean Academy of Sciences, is composed of 14 Societies and 15 Committees that are members or participants in ICSU Unions and Committees. This Committee has had also considerable influence in structuring our national community of scientists and in expressing the views of the working scientists to our national authorities and to society in general.

Chapter XIII FUNDING OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH IN CHILE

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In developing countries it is not easy to quantify resources used in research and development(R&D). In many instances R&D is carried out in institutions without being clearly defined as such. Also, although international definitions to measure research, technology and development are usually employed, these definitions are not always clear and the accounting systems leave room for varied interpretations.

For at least the last ten years the Comisión Nacional de Investigación Científica y Tecnológica (CONICYT) has made studies to determine annual expenditures in R&D. This has meant an improvement of the available information and of the quality of some important indexes. This chapter deals with the issue of resources spent in scientific and technological research, classified by type of institution and funding process. Monetary values are given in real terms (US\$ of 1990).

Six main types of institutions that carry out research are:

1. Institutions of Higher Education, mainly Universities.
2. Research Institutes that belong to the Corporación de Fomento de la Producción (CORFO).
3. Other Research Institutes
4. Public and Private Enterprises

5. Hospitals
6. Other institutions

We classify research funds obtained through competitive processes, such as research grants, under a different category.

1. The main research is carried out in Institutions of Higher Education. About 73% of the researchers belong to such institutions (1988). In 1970, 55% of the funds spent in research were used by these institutions (approximately US\$ 13 millions). By 1990 the amount had more than doubled (to US\$ 28 million) but given the general increase in research funding this amount represents only 28% of total funding.

2. CORFO Institutes, which are state owned have research centers in different specific areas, such as fishery, geology and

technological development. These institutes have had little growth in the last two decades. Research funding of this type has amounted to about US\$ 5 million annually, which in 1970 represented 22% and in 1990 only 6% of total funding.

3. The importance of non-CORFO research institutes, either private or state owned, has increased significantly in the last two decades. Funding of this type has grown from US\$ 4 million (18%) to US\$ 34 million (34%) in 1990. This funding includes research areas such as nutrition, agriculture, forestry, and nuclear energy.

4. Research carried out by public or private industry is difficult to measure, for the above mentioned reasons. The best information available indicates that about 7% of the researchers belong to these enterprises, while research funding, which was practically nonexistent in 1970, increased to US\$ 10 million by 1990 (15%).

5. No reliable data exists on research funds in hospitals. About 450 researchers work in hospitals (1988).

6. No good information is available for other research institutions. Estimates of research expenditures in this category indicate about US\$ 4 million.

7. A growing source of research funding has been research grants, obtained through different agencies. This option became important in the last decade and presently involves about 15 million US\$ (1990). Scientific research is mainly financed through FONDECYT (Fondo Nacional de Ciencia y Tecnología). The amount distributed in 1992 was about 7 million US\$. The main research areas funded were Biology, Engineering Sciences, Medicine and Agriculture. Fundación Andes, a private agency, is becoming increasingly important due to its greater flexibility and rapid response to new requirements.

Research and development in private or state enterprises in collaboration with Universities is funded through a CORFO program (about 7 million US\$ a year). A special program (FONDEF) to fund collaborative projects between industry and research institutions in the areas of agriculture, forestry, mining, manufacture and computers has been implemented for the period 1993-1998. Funding amounts to about 70 million US\$. It is not clear if this funding will continue. FONTEC and Fundación Chile are additional important funding agencies.

Total expenditures in Chile in R&D are about 0.5% of Gross National Product, well below the 2% to 3% spent in developed countries.

CONCLUSIONS AND RECOMMENDATIONS

The scientific and technological progress of Chile is an essential requirement for the advancement of our country in the cultural and socio-economical development.

The world of the XXI century will certainly be one in which scientific knowledge and its technological applications will be the most valued resources as well as basic requirements to compete in the international markets. The comparative advantages of our primary resources will rapidly disappear with the progress of the scientific-technological knowledge, and only those countries that are prepared to produce new knowledge and to use the resulting technologies will improve their quality of life.

The exhaustive study on the present status of Chilean science offered in these pages, in the name of the Chilean scientific community, leads to two major conclusions:

1) Chile has been able to create a small but sound scientific and technological basis; and

2) In order to advance in the coming years, the country has to make a clear and ambitious effort in several aspects that are presently setting limits to our scientific-technological development.

The first conclusion stems from the diagnosis that the scientific community has made of its own reality. Based on this study we now know how many research scientists there are in the country and what do they

work on. We know about their productivity and about their efforts in the training of new scientists. This diagnosis is encouraging because it shows that in several fields of science we have reached scientific levels of excellence, but it is also alarming since it shows that the number of scientists in the country is totally insufficient to supply its needs in the universities, institutes and the industry. The diagnosis also points to a number of factors that are limiting the scientific-technological development.

The Chilean scientific community has decided to take the responsibility to go beyond the diagnosis. We must also offer solutions. Therefore, at the end of this chapter, recommendations on policies and

actions that we deem necessary to carry out are set forth. Particular care has been taken to ensure that the conclusions offered and

specially that the recommendations proposed do represent the broad consensus existing among Chilean scientists.

I. CONCLUSIONS ON THE PRESENT SITUATION OF THE CHILEAN SCIENTIFIC COMMUNITY

1. HISTORY AS A CONDITIONING FACTOR OF CHILEAN SCIENTIFIC-TECHNOLOGICAL DEVELOPMENT

Science and scientists are quite recent phenomena in Chile. The chapters of this book contain a wealth of data, stories and anecdotes of Chilean and foreign scientists who made basic contributions to Chilean science during the colonial times and during the first decades of our independent life. However, the justice of this acknowledgment does not contradict the truth that the contributions of these pioneers were isolated efforts. There is no common thread connecting their work. For many years there was no one in Chile to continue building on the first foundation laid by these pioneers with so much effort and ingenuity.

In general, the exact and natural sciences as an organized activity with continuity in time is a phenomenon which appears in Chile in the second half of the XX century. Biological sciences are an exception, since "genealogical" trees can be traced from pupil to Master which, starting from currently active scientists, go back to the early part of this century and in some cases even to the late XIX century. These "genealogical" trees represent true schools of tradition and scientific thought which are of the essence to provide maturity and soundness to a community of scholars.

In most of these fields of science, however, many members of the first generation of Chilean scientists are fortunately still with us and fully active. The extraordinary drive, remarkable sacrifice and untiring perseverance of this first generation has not been adequately recognized by the country and its society.

The present scientific community, mostly belonging to the second and third generation of scientists, does recognize their founding contribution and offers to them its praise and recognition.

Such a short history and the slow process involved in training research scientists partly account for the small number of scientists that belong to the Chilean scientific community, as well as for its incipient development.

We say that the brief history provides only a partial explanation because there have been other contextual factors that have restricted and distorted the growth and development of science and the national scientific community. The two main ones have been:

A) The political and economical instability which Chile has endured during most of the second half of the XX century;

B) The absence of a national policy granting science and technology the importance and priority they deserve.

The economic instability and the swinging of the political pendulum that we have lived through in our recent history have caused a severe emigration of valuable Chilean scientists. The Directory of Chilean Scientists Residing Abroad which is part of this study collects more than 300 names of research scientists, most of whom are in positions of responsibility in worldwide recognized research centers. Since this directory is far less complete than the one prepared for the scientists working in the country, which includes approximately 1400 names, we could say that an important fraction of Chilean research scientists lives and works abroad. Later on we will return to this subject and to the wealth of potential that this

important group of scientists working abroad represents for our country.

The absence of a State Policy granting priority to science and technology, and viewing its development as a national endeavor, has also been an important factor in limiting the number of research scientists presently available to the country as well as the development attained by our sciences.

Chilean society at large is not yet aware of the importance of local science and technology for its well-being and for securing the future of the country. This lack of perception means that scientists and technologists are undervalued and that their work and ideas are not properly supported. Chile certainly has young people with the intellectual capacity and vocation to become distinguished scientists but the poor economic and social value attached by society to this endeavor discourages a major part of this select group.

The lack of interest of society is necessarily reflected in its political leaders who, in general, have shown little concern for the scientific and technological development of the country. The measures taken to foster this development have lacked the stability and continuity that are necessary to maintain a long term effort, as required in order to build solid foundations for science. CONICYT (National Commission for Science and Technology), created in the late 60's, remained dormant during more than half of its existence. A number of national plans for scientific-technological development only reached the stage of publication and solemn approval to then vanish into oblivion.

Primary and high school education in Chile have a glorious past but, unfortunately, their level has steadily deteriorated in the last decades. This fact, which impacts on every aspect of the national life, has resulted in a teaching of science which is obsolete and devoid of the fascination of this great adventure of the human intellect.

The fact that most of Chilean science and technology is associated to the universities has meant that their development has followed the very negative fate of these institutions in the last 20 years. The political interventions

and economic restrictions suffered by the universities have seriously affected their scientific groups, bringing about their dismemberment and hindering their renewal. On the other hand, it should also be noted that Chilean universities, in general, have not adopted policies aimed at prioritizing the development of their scientific groups or of the science graduate programs. The university structures hinder the formation of interdisciplinary projects and their lack of development policies has prevented them from expanding into new fields of knowledge and modernizing their study plans.

However, in the last few years we have seen an encouraging reinforcement of the national efforts to foster the scientific-technological development and a slow progress in the perception of its importance, at least among the intellectual and leading strata of the country. Notwithstanding, we are still lacking a national policy that provides us with the elements to direct that development.

2. ANALYSIS OF THE NUMBER OF RESEARCH SCIENTISTS

An important part of this study has been to establish how many researchers in exact and natural sciences there are in the country. Most of the work to produce this directory was the responsibility of the Area Committees, which have selected the researchers from a larger group of people participating in research and university teaching of science in the country.

The criteria for this selection were a matter of profound debate by the representatives of the scientific community participating in this study. The first decision taken was to leave the selection in the hands of the Area Committees, formed by specialists who know the work of the researchers of their scientific field. Secondly, it was agreed to use as basic criterion the recent scientific productivity (last five years) of the researcher, as witnessed by in extenso publications in international journals with selective Editorial Committees. Other criteria used were the participation in competitively approved research projects and the continuity in time of his or her research and scientific training. In

general, graduate students or laboratory technologists participating in research were not included. These criteria were adapted to the characteristics of each field.

The result of this effort is a Directory of researchers which we think will be very useful and that deserves a closer analysis.

Table 1 presents the distribution of researchers working in Chile according to areas and disciplines.

Table 2 lists the number of investigators according to the institutions to which they belong.

The first comment to be made concerns the low number of researchers in exact and natural science of the country. A total of 1,342 researchers is a dramatically low figure for the needs and hopes we have for Chile. The selection criteria employed were, according to outstanding scientists with long experience in evaluation of people, the minimal consistent with the aim of the directory, which was to have a list of the active and productive researchers the country has on a stable basis.

Unfortunately this Directory does not include most of the researchers working in applied or technological fields. However, in the biology area medical and agronomic researchers are included. The Chilean Academy of Sciences and the Scientific Societies did not feel to have the required representativity and capability to select researchers in the technological fields. We think, however, that if parameters similar to those used in basic science were applied to those fields we would find a number under 1,000 in all the technologies. We base this estimation on the fact that applied sciences and technologies only account for a 30% of the scientific publications of the country, while occupying a similar fraction of the FONDECYT projects. Obviously, to use the same criteria to select scientific and technological researchers is debatable.

These considerations lead us to conclude that the country has only some 2,500 active researchers. This data would give 0.5 researchers per thousand of active population, which is 10 to 20 times lower than the value for developed countries.

With such limited number of researchers is clearly impossible for science and technology in Chile to fulfill the functions and demands offered by the sector in developed countries. In those countries there are many institutions and industries that assemble in one place more researchers than the total for our country.

The limitations of the Chilean scientific community become more evident and alarming if we analyze the numbers of researchers separately in each field of science. There is an evident incongruity in the fact that a country with more than sixty universities has less than 100 research mathematicians. It is also hard to understand that a mining and seismic country has barely more than 150 researchers in Earth Sciences, and a similar number in Marine Sciences, another area of vital importance for the country. The numbers are even more dramatic if we examine the big sub-disciplines. Here we find only 8 persons doing statistical research, also only 8 in the very important field of oceanographic chemistry. Also, the southernmost country in the world has only two groups studying the ozone hole that exists over the Antarctic and the resulting hazards of the ultraviolet radiation.

Basic research scientists, of which there are so few, are essential for Chile and the Chileans to have a cosmovision adapted to the requirements and realities of the XXI century. These scientists, by the nature of their endeavor, serve as antennae to catch the trends and directions in which the world is going and to show us the oncoming opportunities and problems. Basic science is the most dynamic part of today's culture and, therefore, it plays a fundamental role in the education that our citizens must have. This basic science also produces technological applications that contribute to the solution of major national problems.

There is a plethora of examples illustrating the scantiness of our human resources to both train the best professionals in basic sciences and to deal with practical problems in the major areas of the national economy.

The country needs more plant geneticists and more biotechnologists capable of

TABLE 1

**Distribution of Chilean Researchers According to Science Areas
and Subdisciplines**

Astronomical Sciences		Marine Sciences	
Astronomy of Position	4	Physical Oceanography	5
Stellar Astronomy	18	Chemical Oceanography	8
Extragalactic Astronomy	15	Ecological Oceanography	7
Solar Astronomy	1	Biological Oceanography	33
Interstellar Milieu & Nebulae	8	Marine Biology	94
Planetary System	1	Fishery Management	13
Total Astronomical Sciences	47	Aquaculture and Pathology	22
		Pollution	3
Biological Sciences		Total Marine Sciences	185
Biophysics	36		
Cell Biology	75	Physical Sciences	
Biology of Reproduction	46	Acoustics	3
Biochemistry	86	Applied Physics	12
Botany	48	Atomic and Molecular Physics	7
Ecology	114	Physics of Fluids	11
Pharmacology	55	Physics of Particles	14
Physiology	139	Physics of Plasma	5
Genetics	69	Physics of Solid State	19
Immunology	35	Mathematical Physics	6
Microbiology	34	Nuclear Physics	11
Zoology	66	Gravitation and Cosmology	3
Total Biological Sciences	803	Optics	9
		Dynamical Systems	2
Environmental Sciences		Total Physical Sciences	102
Demography	6		
Patterns	4	Mathematical Sciences	
Air Pollution	28	Computer Sciences	9
Water Pollution	26	Statistics	8
Biodiversity	23	Mathematics	82
Rural Ecology	1	Total Mathematical Sciences	99
Global Change	11		
Total Environmental Sciences	99	Chemical Sciences	
		Analitical Chemistry	19
Earth Sciences		Physical Chemistry	55
Structural Regional Geology	26	Inorganic Chemistry	29
Economic Geology	27	Organic Chemistry	61
Metallogenesis	11	Chemistry of Natural Chemistry	16
Geophysics	16	Environmental Chemistry	22
Atmospheric Sciences	26	Soil Chemistry	3
Geochemistry	13	Water Chemistry	3
Geology	16	Total Chemical Sciences	208
Geography	16		
Applied Geology	3		
Hidrology	13		
Total Earth Sciences	167		
TOTAL OF DISCIPLINES	1,710*	GENERAL TOTAL	1,342*

* The difference between these figures is due to the fact that several investigators are involved in two or more disciplines.

TABLE 2

Distribution of Researchers by Institution

Universidad de Chile	500
Pontificia Universidad Católica de Chile	174
Universidad Austral de Chile	118
Universidad de Santiago de Chile	52
Universidad Católica de Valparaíso	42
Universidad Técnica F.Santa María	38
Universidad Católica del Norte	32
Universidad de Valparaíso	27
Universidad de La Frontera	19
Instituto Profesional de Osorno	17
Universidad de Antofagasta	18
Universidad de La Serena	14
Universidad de Talca	11
Universidad Católica de la Santísima Concepción	10
Universidad de Magallanes	9
Universidad de Tarapacá	6
Universidad de Bío-Bío	3
Universidad Metropolitana	2
Universidad Arturo Prat	1
Universidad de Playa Ancha	1
Otros	128
Total	1,342

producing transgenic plants adapted to our soils.

The country needs more inorganic chemists and more chemical engineers capable of extracting the valuable metals of our salt deposits.

The country needs more embryologists and pathologists of marine species that can maintain the boom of our aquaculture.

The country needs more experimental physicists and more technologists with expertise in non-conventional methods of energy production.

The country needs more bacterial geneticists and more biotechnologists to work in the bacterial leaching of copper.

The country needs more mycologists and more specialists in the clean uses of the waste products of forestry.

The country needs more researchers in informatics and more specialists in the analysis of satellite images.

The country needs more molecular biologists and more virologists to study the diseases of our population.

The country needs more meteorologists and more glaciologists to work on the use and conservation of our Andean and Antarctic ice and snow.

The country needs more pharmacologists and more toxicologists to analyze the effects of atmospheric and water pollution on human health.

The country needs more botanists and zoologists and more specialists to analyze the biodiversity of our flora and fauna and to help to conserve it.

The country needs more chemists to analyze natural products and to give greater added value to our exports.

The list of urgent tasks that Chile must carry out in order to develop and improve the life quality and culture of its people is endless. In all of these tasks we are limited by our human resources in science and technology. We cannot compete at the international level unless we are also at the frontier of knowledge.

Another important conclusion from the analysis of the number of researchers in exact and natural sciences concerns their geographical distribution. There is an alarming centralization of the distribution of researchers in the country. More than 70% of the researchers of the country are located in the metropolitan area of Santiago. Most of the remaining 30% are in the universities of Concepción and Austral de Chile in the X Region and in the institutions of the V region. The age distribution of the selected researchers is also quite disturbing. The percent of them under 40 years old is less than what is required by a country wanting to increase its scientific potential in the next 10 years.

The distribution of researchers by university also points to the great hetero-

geneity of our institutions of higher education. There is an important number of derived universities and almost all the private universities that do not have any researcher in the selected list.

There are many conclusions to be drawn from these figures. One of them is that time and tradition are required to gather important nuclei of research scientists. It is clear that the older universities with more tradition have the largest and more consolidated groups. We also see that there are universities that concentrate their research on specific areas. This picture of institutional and geographical distribution agrees very well with that of scientific productivity and projects approved by FONDECYT. On the basis of these figures it is also easy to determine the institutions which support the country needs in order to structure programs of scientific and technological development as well as intensive human resources training programs.

The clear conclusion that there are many universities where there is little or no research is important, because it should be the basis for policies that define and differentiate the types of institutions of higher education that should exist in Chile. However, at the international level there are many experiences showing that with a strong political decision and enough resources it is feasible to create a university that will become a prestigious research center (Albert Einstein University in New York and the University de Campinas in Brazil are good examples). This was also the case of the Universities of Concepción, Austral and Federico Santa María, in Chile, which a few years after their creation had recruited important groups of professors and researchers. The university law of 1981, that simultaneously created a large number of "derived" universities outside Santiago, was not complemented with a political decision at the level of the central or regional government to give to this new institutions a major impulse. On the contrary, this expansion fell within a policy that greatly restricted state funding to higher education and it also coincided with a severe economical crisis that eliminated the possibility that the private sector collaborated with the development of

the new universities. In spite of there being a new government now and a greatly improved economical situation, a clear decision to support the development of the regional universities is still lacking.

3. QUALITY AND TRAINING OF THE RESEARCHERS IN THE CHILEAN SCIENTIFIC COMMUNITY

Notwithstanding the well-founded concern expressed above on the number of researchers, it must also be concluded that the country has a community of researchers of good quality.

This conclusion can be demonstrated by analyzing the productivity of this scientific community. The epistemometric studies by Krauskopf, presented in the chapter on scientific productivity (Chapter 11), show that Chile occupies the fourth place in Latin America in number of articles in scientific journals indexed by the Institute of Scientific Information. At the beginning of this decade Chile is producing approximately 1200 scientific articles a year. Approximately 60% of these are produced by the small community working in exact and natural sciences.

If we take into account the number of inhabitants, the scientific productivity per capita of Chile is the highest in Latin America. It is hard to comparatively quantify the scientific production per number of researchers in Latin America, because data on number of researchers, defined with criteria similar to those used here, are not available for other countries. From our own data, dividing the publications by the number of selected researchers in our directory, we obtained 0.5 articles per researcher per year, a figure not much lower than that of institutions of developed countries. The circularity of the argument, in that scientists were included in the directory on the basis of their productivity in publication, does not escape us. However, it is also true that this group is responsible for more than 90% of the research projects and works carried out in the country in exact and natural sciences.

The quality of the national scientific community is not only measured by the

number of publications but also by their impact on the scientific world. One of the ways to measure this is the number of citations of Chilean publications made by others. We have seen in Chapter 11 that with this criterion the Chilean publications are also among those of highest quality and impact in Latin America. In particular, there are in Chile areas like Physics that occupy a very outstanding place at the international level. However, though it is necessary and useful to compare the scientific productivity of Chile with that of other Latin-American countries, with which we share so much history and culture as well as problems, it is also necessary to obtain a more global idea of our position at the world level. That reality is much more disturbing, since Latin America, which is coming close to have a 10% of the world population, is only responsible for 1% of the total of scientific publications.

Small developed countries, like Switzerland or Israel, produce more science than all of Latin America.

Another measure of the quality of the scientific community is its graduate training. In the sciences of more recent development, such as Chemistry, Physics and Mathematics, almost all of the researchers have a doctoral degree. In Biology, however, there are many

researchers who did not follow formal graduate programs and that have professional titles such as physician, veterinarian, agronomist, etc. The younger generations of Biologists have also obtained doctoral degrees.

It is interesting to analyze the international influence on the training of Chilean researchers. The great majority of those having the doctoral degree have studied abroad. From the analysis presented in the chapter on postgraduate programs (Chaper 10) the different influences that have affected the various sciences can be determined. For instance, it is evident that most chemists have studied in Europe, while most Biologists studied in the United States. In Physics and Mathematics the European and American influences are more balanced. Given the recent development of the national doctoral programs, the number of researchers that have received the degree in Chile is lower but it is already important.

4. SCIENTIFIC TRAINING
PROGRAMS IN THE COUNTRY -
UNDERGRADUATE AND
GRADUATE STUDIES

Many of the pioneers in the establishment of science in Chile were university professionals with careers that prepared them for

TABLE 3
Economic-Technological Impact at the Beginning of the 1980's.

	Latin America	United States	Japan	Federal Rep. of Germany
Population	8.0	5.0	2.5	1.3
Gross Domestic Prod.	7.0	27.0	9.4	6.8
Manufactured Products	6.0	18.0	11.7	9.4
Capital Assests	3.0	14.7	11.1	9.6
Engineers & Scientists	2.4	17.4	12.8	3.4
R & D Resources	1.8	30.1	10.2	6.7
Scientific Authors	1.3	42.6	4.9	5.4

Percentage of participation with respect to world total.
(Data obtained from Brunner, J.J. Recursos Humanos para la Investigación en América Latina. FLACSO, Santiago de Chile, 1989).

the free exercise of their professions (physicians, engineers, chemist-pharmacists, agronomists, odontologists, school teachers, etc.) Nowadays very few of the professional trained at the universities choose to go into scientific research. There are many factors discouraging them from that, as shall be explained below.

In general, most of the scientists produced nowadays by the country come from those graduating from the science licentiate programs of the universities. There are exceptions, such as the professional titles of biochemist, geologist or civil engineer in Mathematics, that make a significant contribution to those dedicated to scientific research.

There is heterogeneity of the programs and levels of the science licentiate programs currently offered by the different universities. In recent years there was a change in several important universities by which the licentiate program was reduced from 5 years of courses and a thesis to 4 years of courses without a formal thesis. The science licentiate programs are still undergoing a transition, some of them maintaining the longer programs, others granting professional titles to their graduates.

The statistics show that many science licentiate programs do not receive applicants with the high scores that are to be desired for scientific careers and that there is a high rate of desertion. In general the number of graduates with licentiate degrees in the sciences in the country is low, which makes it even harder to propose projects aimed at drastically increasing the number of scientists in the country.

Graduate programs in Chile are also of recent date. The first graduate programs appeared during the 60's but did not go into true operation until the 1970's.

As presented in Chapter 10, the science doctoral programs have only appeared in the Universities with more tradition and a longer history of activities in scientific research. On the positive side it can be concluded that science doctoral programs are of good quality. This conclusion is supported by evaluations carried out by groups of foreign scientists invited by the Fundación Andes and by

national evaluations carried out by CONICYT. These evaluations attested, in general, to the good level of training received by the doctoral students, but also pointed at important deficiencies in the infrastructure and organization of the programs as well as in their duration. In general, the doctoral theses produce several scientific publications in well known international journals, which provides evidence as to their quality. The success of the doctors trained in Chile in centers of international excellence, where they have worked as post-doctoral fellows, also confirms their very good training.

The second positive aspect of these programs is that about an 80% of their trainees are currently working in universities and the industry in the country. Unfortunately the number employed in the industry is very low (approx. 6%). Although we do not have statistics to compare with doctors trained in foreign countries, we are certain that the percent of them that resides abroad is much higher. For instance, according to data of the National Science Foundation, 80% of the foreign students that receive their degree in the United States remain in that country. We could then conclude that the doctoral programs carried out in the country help to prevent the "brain drain". Another positive aspect of the national doctoral programs is that the subjects of the theses are more closely related to the Chilean problems and projects than those carried out abroad.

The negative side of this analysis is the very low number of doctors in exact and natural sciences that the country is producing. In the entire history of its doctoral programs the country has graduated only 247 doctors, with an annual average in recent years of 23 for all these disciplines (Table 3). This is clearly insufficient to supply the great needs the country has to renew and increase its groups of scientists. Even with the low number of scientists currently working in our universities, it is clear that there is an installed capacity to markedly increase the number of doctoral students in exact and natural sciences.

There is a number of factors that have prevented the growth of these programs:

- a) lack of incentives for young scientists to obtain the doctoral degree;
- b) low number of available scholarships;
- c) limited number and fields of specialization of the programs;
- e) lack of support by the universities and by the State.

The Master programs in exact and natural sciences are heterogeneous. In some cases, e.g. in Physics and Mathematics, these programs were established before the doctoral programs, as a preparatory stage for the various groups to deal with the organization of doctoral programs. These programs have been and still are of a higher level than the international Master programs. Most of their graduates go later to doctoral programs abroad or, more recently, in the country. A second type of Master program were generated in areas like Biology and Chemistry, where doctoral programs already existed. These were created to grant an intermediate degree for professional and licentiate leading to specialization. In these cases, the present Master programs do not differ very much in level to the old licentiate programs. A low proportion of these graduates go on to doctoral training.

In general, there is agreement in the area of exact and natural sciences that a person who wants to devote his or her life to research, as academic at the level of Professor, should have a doctoral training.

There is also agreement that Chilean students should be trained in the country up to the highest level that can be offered in Chile, and only then go abroad to complete such training. This opinion of the scientific community implies that no national funds should be used to fund scholarships in areas and levels that can be provided in our country.

5. FUNDING FOR SCIENTIFIC RESEARCH

The major part of the scientific research is funded by the State through the universities and the Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT).

According to data of CONICYT, the percent of national expenditure in research

and development corresponding to universities has markedly declined in the last 10 years. Obviously, these institutions have been severely affected by the State restrictive policies, with research funding taking the biggest cut.

These funding cuts have been partly compensated by the support of the government through FONDECYT, which has grown significantly in the last 6 years.

Presently, in basic sciences, the support that universities lend to research consists mainly in paying the salaries of the researchers and providing the physical infrastructure of laboratories, libraries and workshops. With few exceptions, universities provide very little funding for supplies and equipment for research.

FONDECYT, however, has not been a mechanism capable of supporting young scientists that, after successfully finishing their doctoral or post-doctoral training, go into research with their first projects and one or two undergraduates. This is a very critical stage, since it can determine the entire career of that young researcher. FONDECYT had for a couple of years a separate review process for "initiation" projects, and it would seem necessary to reestablish it to fulfill this need.

The amount of funding for FONDECYT projects does not allow to purchase medium or heavy equipment (with costs over US\$ 15,000). Since for many years there were no funds for equipment, these became obsolete and inadequate, which severely restricted the competitiveness of our experimental research. This situation was partly solved by a project for equipment through an agreement between the Chilean government and the United Nations Program for Development (UNPD). This program acquired and distributed equipment for a total of US\$ 6,000,000 to different Chilean universities, which also provided important financial counterparts. The equipment was allocated through a review process by committees of scientists. This project was certainly important and in some areas, particularly in Chemistry, a major modernization of research equipment was achieved. However, in this review process it became

evident that fulfilling the actual and justified needs of the country in terms of equipment would require and amount 6 or 7 times larger to that granted. The ideal situation would be, of course, that there existed a fund capable of annually supplying the resources to gradually fulfill those needs.

More recently, thanks to the approval of a credit for Science and Technology by the Banco Interamericano de Desarrollo (BID) two other state funds were created: FONDEF and FONTEC. The latter was created to fund projects of research and technological innovation in the industry. FONDEF is aimed at supporting research in universities and institutes in areas of priority for Chilean exports. Due to the requirements of economical return in the short term set for the granting of funding by FONDEF, the approved projects include only a low proportion devoted to research in exact and natural sciences. The scientific community hopes that in the future this fund will be more open to science projects as well as to the support of training programs.

6. INTERNATIONAL COOPERATION

The international cooperation has played a major role in the development of Chilean science and technology.

Private foundations such as the Kellogg Foundation and the Rockefeller Foundation gave an important support to the development of the biomedical area during the 50's and 60's. The Ford Foundation, through the Plan Universidad de Chile-University of California made an important contribution in several scientific areas, particularly in agronomy. The German government, through the DAAD, gave great support to the development of the Universidad de Concepción, particularly in chemistry, and to the Universidad Austral in its areas of forestry and agroindustry. The support of France to mathematics and of Spain to the chemistry of natural products have been very important.

In more recent years there have been important programs of international organizations. The Organization of American States (OAS) has supported the integration of

scientific activities with other Latin-American countries. In biology there has been an important regional program for graduate training, funded by the UNDP and carried out by UNESCO under the sponsorship of ICSU. In biotechnology, projects of the UNDP, UNESCO, ONUDI and FAO, are currently being carried out. In Physics and Mathematics, the OAS and UNESCO have created "Latin-American Schools" and "Regional Centers".

At the national level, the support of the UNDP for the sciences has been very important, since this organization funded during the 80's programs to strengthen the graduate programs in Biology, Physics, Mathematics and Chemistry. Even though the support period was very short, it came when, given the political situation of the country, there were no other sources of official funding. The UNDP, in the late 80's, also made an important contribution by funding applied research projects in collaboration with national industries in the mining, agricultural and forestry areas. We have already mentioned the major equipment program co-funded by the Chilean government and the UNDP.

More recently, with the arrival of democracy, international cooperation for science and technology has greatly increased. We should mention the EULA Program, by which the Italian government supports a vast multidisciplinary project on the Bío-Bío river valley. The European Community and the Swedish government through the SAREC have started important cooperative programs to support projects between European and Chilean laboratories.

The US AID has also been supporting several applied projects. The interest of laboratories in Chile and the United States for collaborating was also evident in the modest but successful program of the Academia Chilena de Ciencias and the AAAS, funded by the Mac Arthur Foundation.

Mention should also be made of the very important support that the International Foundation for Science (IFS) has given to a large number of young Chilean scientists. The IDRC of Canada and the Third World

Academy of Sciences (TWAS) are also institutions that are providing significant support to Chilean science.

A major part of the international cooperation of Chilean science does not proceed through the official channels but it depends on the personal initiative of Chilean scientists that look for and find funding in institutions of other countries for either individual or collaborative projects. The external funds obtained by this mechanism are an important amount. For instance, the Universidad de Chile and the Pontificia Universidad Católica de Chile receive international funds in an amount which is comparable to that received by their researchers from FONDECYT.

The importance of the international cooperation in the training of our research scientists has already been mentioned. Still the

vast majority of our doctors in sciences have received their degrees abroad.

Another important dimension of the international relationships of Chilean science is that of the participation of scientific societies in the International Unions of ICSU and in other multinational organizations and committees. These relationships, while not involving large amounts of funds or resources, are most important since they allow Chilean scientists to know and participate in initiatives of the international scientific community, as well as to present to that community not only their scientific work but also their problems and positions concerning subject matters associated to the condition of scientist. In difficult periods of our recent history the solidarity of the international scientific community was a very important support.

II. FACTORS LIMITING THE NATIONAL SCIENTIFIC DEVELOPMENT

The in depth analysis carried out in this study on the present state of science, added to the experience of the Chilean scientific community, has allowed us to define some of the main factors limiting the national scientific development.

1. SOCIAL PERCEPTION OF THE IMPORTANCE OF ENDOGENOUS SCIENCE

The primary factor limiting scientific and technological development in Chile and in most other Latin-American countries is the lack of perception by their national society of the importance of endogenous science for the cultural and socioeconomic development of the country. Science and technology cannot develop hiding from society but have to flourish in the bosom of that national community. There must be a general conviction that scientific and technological research is one of the most precious tools with

which a country may forge its future and further its creativity. There must also be conviction that in renouncing to produce knowledge through scientific and technological research a country is also relinquishing its intellectual independence, the one independence that conditions all the other capacities a country can have to fight for the development of its people.

Scientific development in Chile has proceeded without the active participation of the national community. We have seen how the history of science in Chile was made by the magnificent individual efforts of a few quixotic scientific pioneers and by the wise decision of some political and university authorities.

The mere fact that society in general ignores the existence of a small but valuable scientific community strongly restrains the development of our activity.

Without the proper social and economical valuation of science and scientists, we will

have few capable young people wanting to devote their lives to this noble task.

Without the social support for the scientific endeavor, we will not get politicians to grant it priority and resources.

Without the social knowledge of the capability of scientists and technologists to face and solve problems, we will not see the national productive sector approaching the scientific community with its problems and bottlenecks.

Without the recognition by the country of the intrinsic value of the search for truth represented by scientific research, we will not be able to develop the universities and institutes to shelter that search and our researchers will emigrate to other latitudes where their work is given a higher value.

2. LACK OF A NATIONAL POLICY OF SCIENTIFIC-TECHNOLOGICAL DEVELOPMENT

As a consequence of the lack of conviction of the Chilean society on the need for endogenous science and technology, Chile has lacked a national policy of scientific and technological development.

The absence of such a policy results in the lack of coordination of the actions taken, and even in the duplication of efforts. The fact that the country does not have a program to increase its human resources in science and technology also points to the absence of a policy considering this a key point for national development.

The fact that Chile does not have a policy for science and technology is due to the absence of an organization with representativity, capacity and authority to generate it.

An organization with the capacity to engender such a policy should gather the opinions, knowledge and responsibilities of the scientific-technological community, government entities and also of the industrial sector.

It would be necessary that this policy provided directions and guidance for the activities in science and technology that are

developed in the different government ministries and areas of socio-economical activities of the country.

3. NUMBER OF RESEARCHERS

We have already discussed this point in the previous sections describing the current state of our science. It is obvious that to do more and better scientific and technological research we need more highly trained researchers. It is also obvious that a rapid increase in the number of researchers in science and technology is not an easy task. Not only we need to encourage capable and enthusiastic young people, and to recover scientists from abroad, but we also need to create jobs in our industry, institutes and universities in order to occupy those researchers in projects of real national importance.

4. TEACHING OF SCIENCES AT THE PRE-UNIVERSITY LEVEL

Certainly one of the factors limiting our scientific-technological development is the low level in the teaching of sciences at the primary and secondary schools. A major part of the lack of perception of Chilean society concerning science comes from this educational deficiency. Also, the lack of interest of the youth of our country for the scientific careers is due to the absence of incentive they received in their early years, in which no one communicated to them the importance and fascination of the scientific endeavor.

The primary reason for this deficiency is the generally poor preparation given, in general, to the teachers at that level as well as to the lack of programs to update and recycle the training of primary and secondary teachers. We should also mention the great overload of teaching hours of this personnel, a fact which prevents them from devoting time to improve their training. The lack of stimuli and the low income of teachers are also factors negatively affecting education.

Another aspect that lowers the level of science teaching is the lack of infrastructure of laboratories, teaching material, textbooks and libraries.

5. FINANCIAL SUPPORT FOR PROJECTS OF DEVELOPMENT AND TRAINING OF HUMAN RESOURCES

We have seen that in the last 6 or 7 years the country has made an important effort to provide a significant funding to FONDECYT, mechanism that supports scientific and technological research projects using as main selection criteria the quality of the projects and that of the responsible research scientists. Nowadays this mechanism finances most, but not all, the good projects of the established research groups of the country.

However, this mechanism does not carry out two very fundamental functions for the scientific development:

- The development of new areas of science that, for obvious reasons, lack established laboratories in the country.

- Support to young research scientists who want to start a scientific career. The young scientists are in a bad position to compete with laboratories with a long history and should be evaluated more on the basis of their potential and training than on their productivity.

The projects to develop areas of science and technology are obviously very different from the specific projects of an individual laboratory. One of the more evident differences is that development projects should be presented by institutions instead of individuals.

Another factor limiting scientific development from the viewpoint of funding is the poor support given to the programs for the training of human resources. The number of graduate scholarships granted is very limited and the doctoral and Master programs do not receive support for their important activities. The graduate programs also need support at the level of libraries, informatics services, short scholarships for research visits, visiting professors to give courses and to participate examining commissions.

6. REMUNERATION OF THE RESEARCHERS

The remunerations received by the researchers in science and technology in Chile have a level clearly insufficient to cover the needs of a family in our country. This is particularly true for those working as university professors, i.e. the great majority of them.

The salaries of the researchers are 3 to 5 times lower than those received by researchers with similar qualifications in the developed countries. Of course this difference encourages the emigration of the Chilean researchers. In addition, in Chile the remunerations of university professionals with shorter and less demanding careers to that of an researcher, who requires a doctoral degree, are also significantly better. This obviously discourages young people with above average capacities to follow a scientific career. In the last few years, the rules of the FONDECYT projects have made it possible to include salary supplements as part of the budget. This has been an important palliative for the problem of remunerations. However, the mechanism of salary supplements through research projects has several drawbacks, such as the fact that there are only two categories of researchers and that individual output is not assessed for each person.

7. LOW LEVEL OF RESEARCH AND DEVELOPMENT IN THE INDUSTRY

Contrary to what happens in developed countries, where most of research and development is made by industry, in Chile most of it is carried out in the Universities. According to data of CONICYT in Chile the industry provides only around 10% of the national investment in research and development while in the United States and France the corresponding figure is 50%, in Germany 65% and in Japan, 70%.

Another data illustrating this problem of scientific research is that out of a total of 247 scientists graduated with a doctoral degree in Chile only 14 are currently working in industry. The low level of research carried out in the industrial sector is both cause and effect

of the lack of relationship between the productive sector and the scientific-technological sector located in the universities.

8. LACK OF DIALOGUE BETWEEN THE SCIENTIFIC COMMUNITY AND GOVERNMENT OFFICIALS

Another factor limiting the scientific-technological development in Chile is the scant contact between the scientific community and government officials.

The Presidency of the Nation does not have an Office of Scientific Advisor and the Ministers do not have mechanism of consultation with scientists in the many topics on which they take decisions and which should include scientific-technological considerations. The official visits abroad of the President and Ministers never include in their entourage scientific personalities that could further the international relationships of our science.

The scientific community has recently succeeded in fostering the creation of a Commission on Science and Technology in the House of Representatives, but the same has not yet been accomplished in the Senate.

Certainly the most negative factor in this context is the absence of an entity to generate a national policy for science and technology, an entity which should include scientists and technologists as well as government authorities and representatives of industry.

9. SITUATION OF THE UNIVERSITIES

As already mentioned, the major part of the science in Chile is done at the universities and therefore the critical situation of our universities has a very negative impact on the

scientific-technological progress of our country.

The situation of the universities comes partly from the restrictive policies suffered by their budgets in the last twelve years. These policies have prevented hiring new qualified personnel and has reduced the financial support to scientific research programs by these institutions.

It must also be taken into account that the universities, in general, have not adapted to the circumstances and changes that have taken place in the country and the world. The need to change structures, to make the academic staff more efficient, to modify and make more flexible the study programs has not been faced by the universities. Particularly important for the scientific-technological development of the country has been the fact that these institutions have not created development programs and plans in the new areas of science that have arisen in the last years, and that scientific research has received very low priority among university activities.

10. THE CENTRALIZATION OF THE SCIENTIFIC-TECHNOLOGICAL DEVELOPMENT

The fact that more than 70% of the scientific-technological research is carried out in the metropolitan area of Santiago is negative for the science and technology of the country. This centralization tends to increase the gap between research activities and the problems faced by other regions of the country, where an important part of the national wealth is created. Also, the extreme scientific centralism hinders the development of regional universities and contributes to make a major part of the national community view science as something distant and useless.

RECOMMENDATIONS

variable of science and technology into the political decisions of the State and those that propose the creation of programs of activities to stimulate the scientific-technological development of the country.

The study of the present reality of the Chilean science and of the factors limiting its development, leads us to make a number of recommendations. These can be divided in those that involve the creation of a mechanism or procedure to incorporate the

A. CREATION OF MECHANISMS AND PROCEDURES TO INCLUDE THE VARIABLE OF SCIENCE AND TECHNOLOGY IN THE POLITICAL DECISIONS

1. PRESIDENTIAL ADVISORY COUNCIL TO CREATE A NATIONAL POLICY OF SCIENCE AND TECHNOLOGY

A modern State requires an entity that gathers a general view of the science and technology in the country, having access to in depth studies on its situation, its problems and its opportunities. An entity with that view and knowledge will then have the responsibility to design a national policy providing lines of action and priorities to achieve the development of the science and technology in the country.

This entity, with the structure of a Council, would act as Advisor to the President through:

a) The proposal of national policies to stimulate the development of science and technology and its applications.

b) The preparation of recommendations aimed at coordinating the action of the different sectors and mechanisms involved in the scientific-technological activity of the country.

c) The opinion on the allocation of state resources to the different instruments responsible for furthering this development.

This Council must have as members active scientists and technologists who are representative of the scientific-technological community of the country.

2. ADVISERS TO GOVERNMENT MINISTERES

It is proposed that the main public offices (Ministries or major autonomous corporations) should designate a scientist or technologist of renown as adviser in matters of science and technology. Besides an advisory role, this person should have the responsibility of acting as a link between the authorities of that office and the scientific community. Part of that function would be to inform the scientific community about the policies, programs and priorities of the institutions, and

at the same time to inform the public officers of the opinions and suggestions of that community.

3. USE OF THE CHILEAN ACADEMY OF SCIENCES AND THE SCIENTIFIC SOCIETIES TO MAKE STUDIES AND PROVIDE OBJECTIVE OPINIONS ON SCIENTIFIC-TECHNOLOGICAL MATTERS OF NATIONAL IMPORTANCE

Both the executive government entities and the parliament need objective opinions and in depth studies on different scientific-technological matters of great national importance.

Examples:

- making a patent law would require knowing the projections of the transgenic organisms that are being patented in other countries.

- drawing a regulation on water pollution would require opinions on the usefulness and limitations of the microbiological methods of waste processing.

- etc.

The Chilean State should ask the Chilean Academy of Sciences and the Scientific Societies with longer history to carry out studies to objectively evaluate the situation and to recommend alternatives from a technical viewpoint.

4. PARLIAMENTARY COMMITTEES

Both Houses of Congress require the existence and functioning of Committees on Science and Technology. Such committees have been created in the parliaments of most of the developed countries to broaden the analysis of the scientific-technological variables of many legislative decisions, to regulate and coordinate the national efforts in this field, and to serve as a link to the scientific-technological community.

5. SCIENTIFIC ATTACHES IN SOME CHILEAN EMBASSIES AND PARTICIPATION IN PRESIDENTIAL MISSIONS ABROAD

An important part of the scientific-technological development depends on fluent

and active international relationships, which are frequently expedited by means of official institutions and agreements between governments.

Also, in the developed world there often appear opportunities that could benefit Chilean researchers. Therefore, it is important that the country maintains and increases its recent policy of naming scientific attachés in 6 to 10 capitals of particular importance for the scientific relationships of Chile. It is also very important that these scientific attachés help to maintain the contact with the many Chilean scientists living abroad and whom we want to incorporate in our efforts to develop science and technology.

Furthermore, these attachés should maintain active contacts with the national scientific community and its entities.

In recent years a major part of the international contacts have taken place during presidential visits that include a retinue representing various sectors of the national life. It would be important that they also included active scientists who could foster exchange programs and collaborative projects. It would also be important to give Chilean scientists traveling abroad the official mission to stimulate contacts with scientific institutions of both private and public nature.

B. PROGRAMS OF ACTIVITIES TO STIMULATE THE SCIENTIFIC-TECHNOLOGICAL DEVELOPMENT OF THE COUNTRY

1. PROGRAM FOR INCREASING HUMAN RESOURCES FOR SCIENCE AND TECHNOLOGY

The most pressing need of the country in the scientific-technological field is to alleviate the scarcity of highly qualified human resources. Therefore, we propose that the country should undertake an ambitious program aimed at doubling the number of researchers in the next ten years. Ideally, all the new researchers should have the doctoral degree.

A program with such a scope should:

- stimulate and reinforce the science licentiate programs that feed the scientific graduate programs;
- stimulate and reinforce the national doctoral programs;
- attract an important number of Chilean researchers now living abroad as well as foreign researchers;
- provide scholarships to study abroad for graduate students in areas that do not have a critical mass in Chile;
- create jobs in the industry and university positions that use adequately the new researchers.

Each of these points will be briefly discussed.

• To stimulate the science licentiate programs

The doctoral programs in science and technology are to a great extent nourished by students graduating from the science licentiate programs. For this reason, in order to have a successful program of human resources for sciences, it is imperative to strengthen and improve the level of the licentiate programs. Obviously this part of the program must be carried out jointly with the university faculties that offer the licentiate degrees, and such program should also include, among other activities: recruiting and granting scholarships to encourage the enrollment of highly qualified students; modernization and flexibilization of the curricula; reducing the number of years required for graduation as licentiate; improving the level of training through better prepared teaching staffs; improving the teaching material infrastructure, the equipment of teaching labs, libraries..., etc.

• To stimulate and reinforce the doctoral programs

As already discussed, the current doctoral programs in Chile are of good quality but graduate a clearly insufficient number of doctors (approximately 23 a year). In order to accomplish the proposed goal this should be gradually increased to reach some 200 doctors a year by the end of this decade. To achieve this it would be necessary to greatly increase

the available scholarships and quotas in the existing programs, to create new programs and to continually evaluate their performance so as to maintain the existing high level. It would be necessary to renovate laboratories and libraries and to modernize the equipment. It would also be imperative to increase the number of tutors through the incorporation of scientists living abroad and through international cooperation programs. It is also deemed important to create programs of institutional support for universities presenting projects to create or reinforce science graduate training programs.

- **To attract scientists living abroad**

The directory of Chilean scientists living abroad and the survey answered by an important number of them show that it would be possible to attract some 200 of them in a 4 year period. This possibility would not be open only to Chileans but also to highly qualified foreign scientists.

It would be essential that such a recruiting effort were carried out on the basis of development plans that define priority areas and that insure a significant counterpart by the institution receiving the scientist. The contracts would be decided through an evaluation process by specialists in each field.

Besides recovering these valuable members of the Chilean cultural heritage, it is considered essential to reestablish links with the Chilean scientists who want to remain abroad. They could become a true "diplomatic corps" for Chilean science and support its development through their many connections.

- **Graduate scholarships to study abroad in areas without critical mass in Chile**

There are several areas and sub-areas of the basic sciences and particularly of technologies that do not have yet critical mass to offer a good level doctoral program in Chile. The country should organize scholarship programs for studies abroad using in most cases foreign technical cooperation funds, but with clear stimuli for the students to return to Chile upon completion of their studies. It

should be clear that an important part of these graduates will participate in staffing new doctoral programs that will broaden the training possibilities in the country.

- **To create jobs in the industry and university positions for the new researchers**

A rapid growth of the number of researchers such as the one proposed requires a program to stimulate the creation of jobs that will take advantage of the high level training of the new researchers. There must be programs encouraging the hiring by the industry, productive sector and research institutes, of an important part of the young scientists trained in the country. Supporting research and development projects of the industry which include as new personnel doctors in science and technology could be one way. Post-doctoral scholarships for young researchers participating in projects in industry could be another. Also, industry personnel should be granted fellowships to develop training and specialization programs.

It is rather alarming that a high proportion of the researchers working at the universities are older than 50 years. It is also symptomatic that more than 75% of the academic staff of our universities do not qualify as researchers. To face this serious problem the universities should have a policy of academic evaluation and a retirement incentive program.

Academic evaluation with demanding standards of quality, efficiency and dedication is the best mechanism to replace the professors with low performance with young or experienced researchers with good training. A policy of economic incentives for retirement after the necessary time period would be one of the best mechanisms to make available positions for the new researchers.

The increase in number of Chilean scientists should also be used to decentralize scientific and technological research. This could be achieved through a policy for the development of regional centers as well as important incentives for those researchers who choose to take positions in the new provincial universities.

C. A SYSTEM OF FINANCIAL STIMULUS FOR THE RESEARCHERS

One of the ways in which a society recognizes the importance and value of an activity is through the salary paid to those that perform it. In Chile scientific research is remunerated poorly. Young science doctors are paid 4 to 5 times less than what they would get in a developed country, and for senior scientists, with more than 20 years of experience, the difference is still at least 3 fold. This is certainly one of the causes for the emigration of our scientists. Also, there are important differences between the earnings of a scientist and those of a professional (physician, engineer, agronomist) in the country. This partly explain why so few highly qualified young people choose a scientific career.

To correct this situation is complex and expensive. One of the complexities is that most of the researchers are university professors but not all university professors are researchers. In the Chilean university system, represented by the Council of Rectors, there are approximately 15,000 professors, while in the country there are approximately 2,500 researchers. While the university has the duty to properly remunerate its professors, the country should give a stimulus to the researchers for its valuable and essential contribution to the country.

This has led the other four Latin-American countries that share with Chile the leadership in science and technology (Argentina, Brazil, Mexico and Venezuela) to adopt national systems, similar to that of Frances CNRS or those of other European countries, by which researchers are evaluated, placed in different levels on a scale and given a financial stimulus. This system has been well received by the researchers of those countries, particularly in Mexico.

In Chile the FONDECYT projects are being used to complement the salary of the researchers. As already mentioned, this system has several drawbacks, e.g. that there are only two levels: responsible researcher (only one) and collaborating researchers. This occurs despite the fact that often two researchers of

the same capacity participate in the same project. Another problem is that the inclusion of salary complements often distorts both the structuring and evaluation of the projects.

There is agreement among the scientific community that Chile must urgently adopt a national system of researchers with the following characteristics:

1. national evaluation by committees of scientists of the highest level,
2. open review process for all those who want to be evaluated and fulfill the requirements,
3. grades in a scale including 4 or 5 levels defining clear stages in the development of the researchers,
4. the evaluation must be periodical and all the researchers in the system must submit their curricula every three years, either to remain in the same grade or to advance. Those that do not qualify will leave the system regardless of having been included previously.

D. A PROGRAM TO IMPROVE SCIENCE TEACHING

Scientific and technological development is closely related to the teaching of sciences at the primary and secondary schools. The poor scientific-technological education provided in most schools of our country is to an important degree responsible for the poor perception that Chilean society has of this sector.

A program to raise the level and quality of that teaching must be centered on the retraining and updating of the professional instructors responsible for teaching science to Chilean children. The national scientific community is willing to work with the Ministry of Education and other institutions involved to help prepare teachers better. It is important to have personnel qualified to work with the teachers and that scientists participate in the preparation and evaluation of educational Programs.

Such a program should also include the improvement of teaching infrastructure: textbooks, libraries, videos, laboratories, computer systems, etc.

Competition programs, such as the science Olympiads, are highly stimulating to

students and teachers. Programs of "students in research", in which outstanding high school students spend summers in research labs, should be also encouraged.

E. SCIENCE POPULARIZATION ACTIVITIES

Science and technology will only grow in Chile if society is convinced of its importance and usefulness. To attain this objective a well structured effort must be made to communicate to the national public the great projections of science and technology for the future of the country and the need for scientific-technological research to maintain and increase our competitiveness in international markets as well as for our social development.

Such a program must be centered on the training and preparation of public communicators who understand the consequences of scientific-technological research in the country and who can deliver this message to the public through television, radio, newspapers and books. Of course the members of the scientific community will have to collaborate very actively with this program, making efforts to explain their works, achievements and problems to the public in an understandable manner.

This effort should include the publication of human aspects of science and technology (biographies and histories of important findings), which often contributes to a better public image of science.

The creation of popularization programs designed for specific sectors of society seems an efficient strategy. For instance, there could be programs specifically addressed at personnel in government, in industry or in teaching.

Science and technology museums are also useful media to communicate to society the importance of science.

F. STIMULUS TO SCIENTIFIC-TECHNOLOGICAL RESEARCH IN THE INDUSTRY

The national scientific-technological development requires an important increase of the amount of work in research and development in the industry. A program aimed at such an increase should include:

- tax incentives and special credits for industries that propose research and development projects;
- incentives to industries that hire scientists and technologists with higher degrees;
- a forum for the members of the scientific-technological community and industry to maintain an active dialogue and exchange of information;

G. RELATIONSHIP OF CHILEAN SCIENCE WITH THE INTERNATIONAL SCIENCE

A program of scientific-technological development should take into account the important aspect of international relations. Science and to a lesser degree, technology, are activities of an international character. Even in the more advanced centers scientists are nourished by the ideas and advances taking place elsewhere in the world. The flow of information through electronic and printed media is of the essence but it does not replace the creativity arising when two scientists with common interests meet and exchange ideas.

In spite of many efforts, Chilean science is still isolated. Chilean scientists are, in general, behind in news and our experiments and proposals are not discussed and criticized enough to reach the degree of perfection reached in countries where research is more up to date. It is necessary to work more to break that isolation. A program aimed at achieving that should include:

- funds to finance 2 year post-doc and "sandwich" scholarships for doctoral students;
- funds for an active exchange of researchers;
- visits of foreign professors to participate in research projects and activities of the doctoral programs and scientific meetings;
- organization of international workshops and symposia;
- funds for collaborative projects between Chilean and foreign labs.

The participation of our scientific societies in the international unions of ICSU and the collaboration in international projects of interest for Chile should be encouraged and financed.

A special aspect of this program should be centered on our scientific relationships with Latin-American countries. The scientific integration of the region is necessary and beneficial for Chilean society. We have at the same time a lot to give to and a lot to receive from our neighboring countries.

H. FOSTERING OF SCIENCE AND TECHNOLOGY IN THE REGIONS

To boost decentralization it would be important to structure programs that, safeguarding the levels of the projects and proposals, stimulate the scientific technological development in the Regions.

These programs should be particularly careful of linking the projects with the interests and problems of the corresponding Region. Also they should encourage projects

of collaboration between the traditional universities and the less developed ones with the aim of improving the level of the latter.

I. SCIENTIFIC INFRASTRUCTURE

It is imperative for Chile to have a program to improve the scientific infrastructure and to which institutions may apply. The modernization of research and teaching equipment is essential.

It is also fundamental to improve and complete libraries and to extend the informatic networks and the communication with data banks.

The establishment of workshops, animal and plant facilities as well as other services should also be included in the scientific-technological infrastructure.

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